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RELATIONSHIP BETWEEN PHYSICAL PERFORMANCES OF SCHOOL-AGE CHILDREN AND THEIR AGES, HEIGHTS, AND WEIGHTS.

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RELATIONSHIPS BETWEEN PHYSICAL PERFORMANCE AND THE CHARACTERISTICS OF AGE, HEIGHT, AND WEIGHT OF PUPILS WERE INVESTIGATED TO FORM A BASIS FOR AN IMPROVED CLASSIFICATION INDEX TO ASSIST IN EVALUATING PHYSICAL FITNESS TEST SCORES. THE AMERICAN ASSOCIATION FOR HEALTH, PHYSICAL EDUCATION, AND RECREATION (AAHPER) YOUTH FITNESS TEST WAS ADMINISTERED TO 28,000 CHILDREN FROM GRADES 4 THROUGH 12, IN A SAMPLE OF 100 SCHOOLS. PERFORMANCE SCORES, GRADE, AGE, HEIGHT, AND WEIGHT WERE USED TO DEVELOP NORMS FOR THE TEST. A MAJOR FINDING IS THE NECESSITY FOR TAKING A PUPIL'S AGE, HEIGHT, AND WEIGHT INTO ACCOUNT IN THE INTERPRETATION OF HIS TEST PERFORMANCE. (JC)

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Title: Relationship between Physical Performances of School-age Children and their Ages, Heights, and Weights

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I Introduction

A. The Problem

During the past several years a great deal of attention has been given to the improvement of the physical fitness of the American people. In 1958 the Association for Health, Physical Education and Recreation developed the National Youth Fitness Test and normed it on a national sample of school-aged children. To aid in the interpretation of the performance scores obtained in an administration of the test, a "Classification Index" which consisted of a combination of the age, height and weight of the children being tested was devised.

Recent research has cast some doubt on the usefulness of height and weight in the interpretation of the physical fitness test scores of school children.[1] All previous reported studies of the relationship between physical performance and height and weight have assumed that the relationships, if any existed, were linear. However, logical analysis of these relationships suggests that they might be nonlinear. For example, if age and height are held constant, there may be an optimum weight at which the greatest levels of performance are attained. Children who are much lighter might lack the physical strength to equal the performance level of the more well-developed children in the optimum weight class. On the other hand, children who are much heavier for their height and age, might not be able to equal the performance level attained by somewhat lighter children, because their muscular development is more than offset by their additional weight. If the relationship between physical performance and any of the three characteristics of age, height and weight is nonlinear, linear regressions and correlations on these characteristics would be of a low magnitude. An investigation of the relationships between physical performance and the characteristics of age, height and weight of pupils is necessary as a basis for an improved classification index to assist in evaluating the physical fitness test scores of school pupils.

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[1] Espenschade, Anna S., Restudy of Relationship Between Physical Performance of School Children and Age, Height and Weight. Research Quarterly, 34:2 : 144-153 May 1963.

B. Objectives

The objectives of the research project are:

1. To determine the suitability of a nonlinear function for expressing the relationships between the physical performance of school children on the AAHPER Youth Fitness Test and each of the children's characteristics of age, height and weight.

2. To determine the nature and magnitude of these relationships.

3. To develop a multiple, nonlinear regression of physical performance scores on the independent variates of age, height and weight.

4. To prepare, from the coefficients of the multiple nonlinear regressions, a new Classification Index in tabular or graphic forms for use in evaluating pupils' performances

on the AAHPER Youth Fitness Test.

5. To determine the feasibility of combining the item scores on the test into a composite score which would represent the relative overall fitness of a school youth.

6. To provide a basis for evaluating future experimental programs which can determine the effect of changes in the physical education programs of schools.

It should be stressed here that objectives 2, 3, and 4 of the foregoing set are conditional upon the findings obtained in connection with objective 1.

C. Other Related Research

The literature describing research on the relationship between physical performance and the characteristics of age, height and weight was reviewed by Gross and Casciani[1] in 1962, and by Espenschade[2] in 1963. These reviews reported that small but positive relationships had been found between performance of physical test items and age, height, and weight. In their own research conducted on 13,000 Pennsylvania school children, Gross and Casciani reported small but positive relationships between performances on the AAHPER test and age and height. They found small but negative correlations between performance and weight. When all three factors were combined in a multiple regression, small but positive relationships were found. Gross and Casciani concluded that age, height, and weight could be disregarded in establishing norms for the AAHPER test for use with school children. It should be pointed out that the Gross and Casciani study did not explore the possibility that the relationships studies might be nonlinear in character. Earlier studies viewed by them also did not explore the possibility of the relationships being nonlinear.

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[1] Gross, Elmer A., and Casciani, Jerome A., The value of age, height, and weight as a classification device for secondary school students in seven AAHPER Youth Fitness Tests. The Research Quarterly, 33:1 : 51-58, March 1962.

[2] Espenschade, Anna S., Op.Cit.

In the Espenschade study small but positive correlations were reported for performances on the California Physical Performance Test of California school children. The author did report a continuous progression in performance with respect to age. Espenschade concluded that classification according to age alone was desirable in establishing norms for the California test. Again, in the Espenschade study no attempt was made to determine if the relationships between performance scores and age, height, and weight might be nonlinear.

Thus, as far as can be determined from the literature herein reviewed, no previous effort has been made to determine the nature of the relationships between physical performance scores on the AAHPER and the pupil characteristics of age, height, and weight.

II Methods and Procedures

A. Experimental Design

During November of 1962, the AAHPER Youth Fitness Test was administered to the children of grades 4 through 12, in a randomly selected sample of 100 Minnesota schools. In this program approximately 28,000 children were tested. The performance scores, grade, age, height, and weight for each child were punched on an IBM card. These data were used to develop Minnesota norms for the test.

The AAHPER test consists of seven items as follows: 1) Pull-ups, 2) Sit-ups, 3) Shuttle run, 4) Standing broad jump, 5) 50-yard dash, 6) Softball thrown for distance, 7) 600-yard run/walk. There is no composite score. The procedures described were carried out separately for each of the test item scores with the exception of items 1) Pull-ups, and 2) Sit-ups. The reason for the exclusion of these two items was the very severe degree of non-normality which characterized their frequency distributions. The distribution of pull-ups scores was extremely skewed. The distributions of the sit-up scores were extremely multimodal. These findings were made by the authors of this project in an unpublished study in which the performance of Minnesota children on the AAPHER test were evaluated in terms of the published United States norms.

A hypothesis which may be stated in general form is as follows: There are no nonlinear functions which can express more accurately than can the linear function the relationships between the pupil characteristics of age, height, and weight, taken

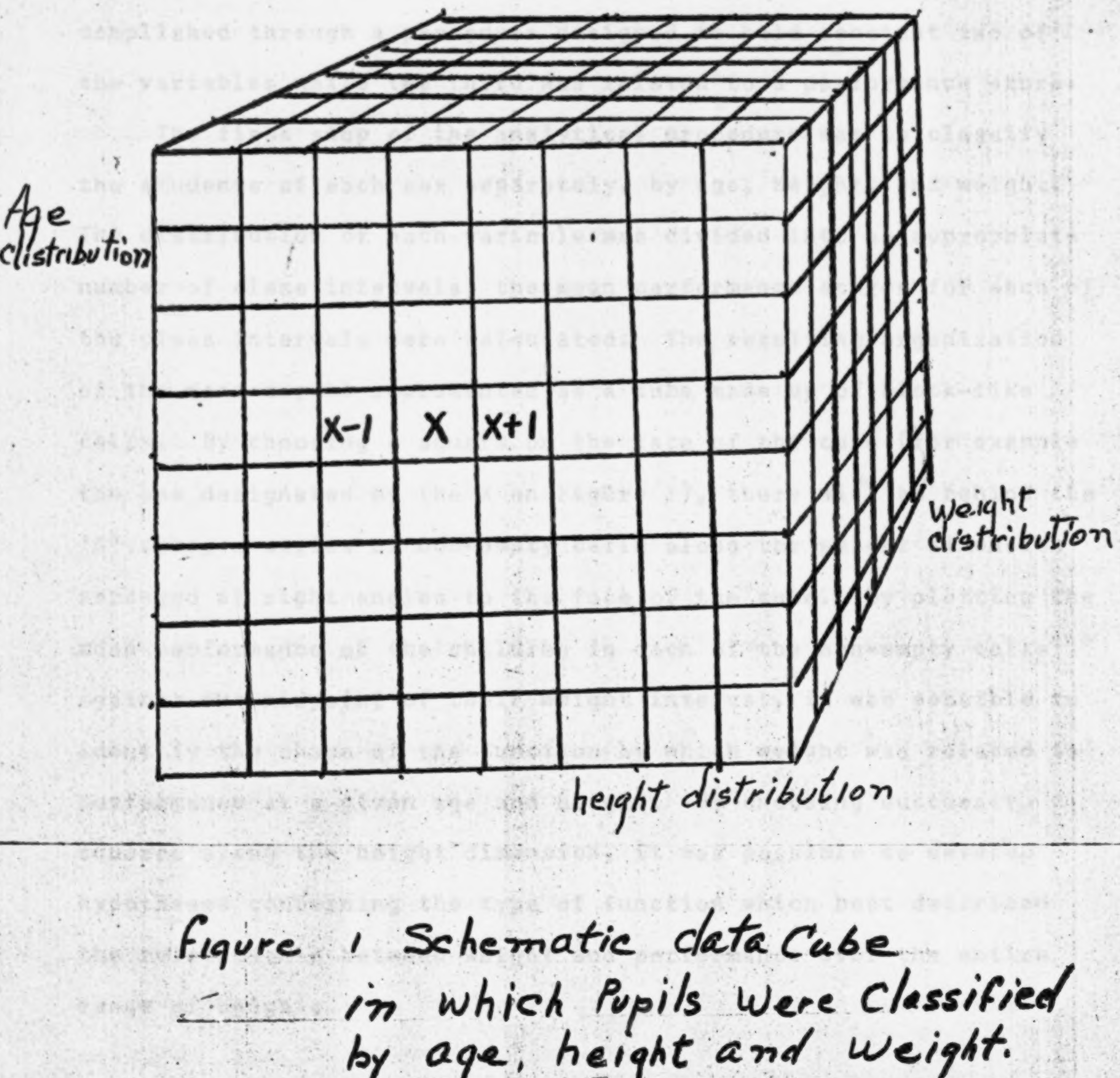

figure 1 Schematic data Cube in which Pupils were Classified by age, height and weight.

singly or in any multivariate combination, and pupil performance scores on the AAHPER Youth Fitness Test.

It was first necessary to determine the general shape of the functions by which performances are related to each characteristic. Then the general shapes of the distributions were described in precise formulas which were tested empirically. This was accomplished through a procedure designed to hold constant two of the variables while the third was related to a performance score.

The first step of the analytical procedure was to classify the students of each sex separately, by age, height, and weight. The distribution of each variable was divided into an appropriate number of class intervals, the mean performance scores for each of the class intervals were calculated. The resulting organization of the data may be represented as a cube made up of block-like cells. By choosing a square on the face of the cube (for example the one designated by the X on Figure 1), there will be behind the 'X' cube, a series of non-empty cells along the weight dimension arranged at right angles to the face of the cube. By plotting the mean performance of the children in each of the non-empty cells against the midpoint of their weight interval, it was possible to identify the shape of the function by which weight was related to performance at a given age and height. By choosing successive squares along the height dimension, it was possible to develop hypotheses concerning the type of function which best described the relationship between weight and performance over the entire range of heights.

By placing these plotted relationships parallel to each other according to the height intervals they represent, it was possible to generate a three-dimensional surface which represented the relationship between each of the performances and height and weight with age held constant. From successive analyses in which each pair of the three independent variables were held constant, a series of hypotheses were generated concerning the functions most appropriately descriptive of the relationships between each of the pupil characteristics and each of the performance scores.

The resulting hypotheses were tested using an electronic computer programmed to a nonlinear regression analysis. One such program is the SNAP multiple, nonlinear regression program for the IBM No. 7090 electronic computer. This program is designed to solve a regression equation and yield appropriate regression coefficients for independent variables which are related to the dependent variable through any of 21 different functions. In addition to the regression coefficients the program will yield tests of the significance of the regression coefficients and effectiveness of the regression equation. In addition, it will also provide a comparison of the advantage of the multiple nonlinear regression over the linear regression in terms of the portion of the total variance of the dependent variable which can be accounted for by each. Furthermore, the significance of the contribution to the regression of each of the independent variables can be tested in a similar manner.

Norm tables were developed using a form of standard scores obtained from the following formula:

$$\text{Standard performance score} = \frac{\text{actual performance score - predicted performance}}{\text{standard error of estimate of the nonlinear regression}}$$

The resulting tables will allow a child's performance to be compared quickly with that which can be expected of a child of similar age, height, and weight. An attempt will be made to combine the standard scores for items thus derived into a composite score.

B. Sampling Procedure

As was previously mentioned, the AAHPER was administered to the children of grades 4 through 12 in 100 randomly selected schools in Minnesota. The numbers of children of each sex and each grade level for whom test scores, age, height, and weight data were obtained, are shown in Table 1.

The difference in cost of running the entire group shown in Table 1 rather than a sample of them through a computer in the regression analysis, would be nearly offset by the cost of using the computer to select a random sample. Furthermore, with the larger number of children it was to be expected that the number of empty cells in the data cube would be minimized.

C. Data

For this project the data consist of the following:

1. Pupil performance scores on the AAHPER Youth Fitness Test.
2. Age in months.
3. Height in inches.
4. Weight in pounds.

Table 1

Pupil Placement in Testing Sample by Grade and Sex

	Sex		
Grade	Male	Female	Total
4	1494	1482	2976
5	1450	1464	2914
6	1515	1441	2956
7	2255	2135	4390
8	2114	2301	4415
9	2414	2515	4929
10	2650	2689	5339
11	242	288	530
12	193	171	364
Total	14,327	14,486	28,813

III Analysis of Data

There is an infinite number of nonlinear functions by which the pupil characteristics of age, height, and weight might be related to the five physical performances. The first steps of the analysis were to eliminate as many of these as possible.

A. Derivation of Hypotheses. It was necessary then to develop specific regression equations for each of the functions which appeared to be feasible. The resulting equations became the formal statements of the hypothesized relationships which were tested empirically. To help formulate these statements one three-way frequency distribution of the female students and one of the male students with respect to age, height, and weight were constructed. Three-month age intervals, two-inch height intervals, and five-pound weight intervals were selected arbitrarily for both the girls' and the boys' distributions.

The data cubes formed by these three-way frequency distributions could be rotated so that they could be viewed from any aspect. For example, the cube may be turned so that it is viewed with the age dimension held constant, that is with the age axis vertical, the height dimension horizontal and oriented from the viewers left to right, and the weight dimension horizontal but pointing away from the viewer. Thus, at any given level of the cube (equal age levels) the cells along the face of the cube from left to right represent increasing height categories and the cells extending back the depth of the cube represent increasing weight categories. The frequency distribution consisted of the count of

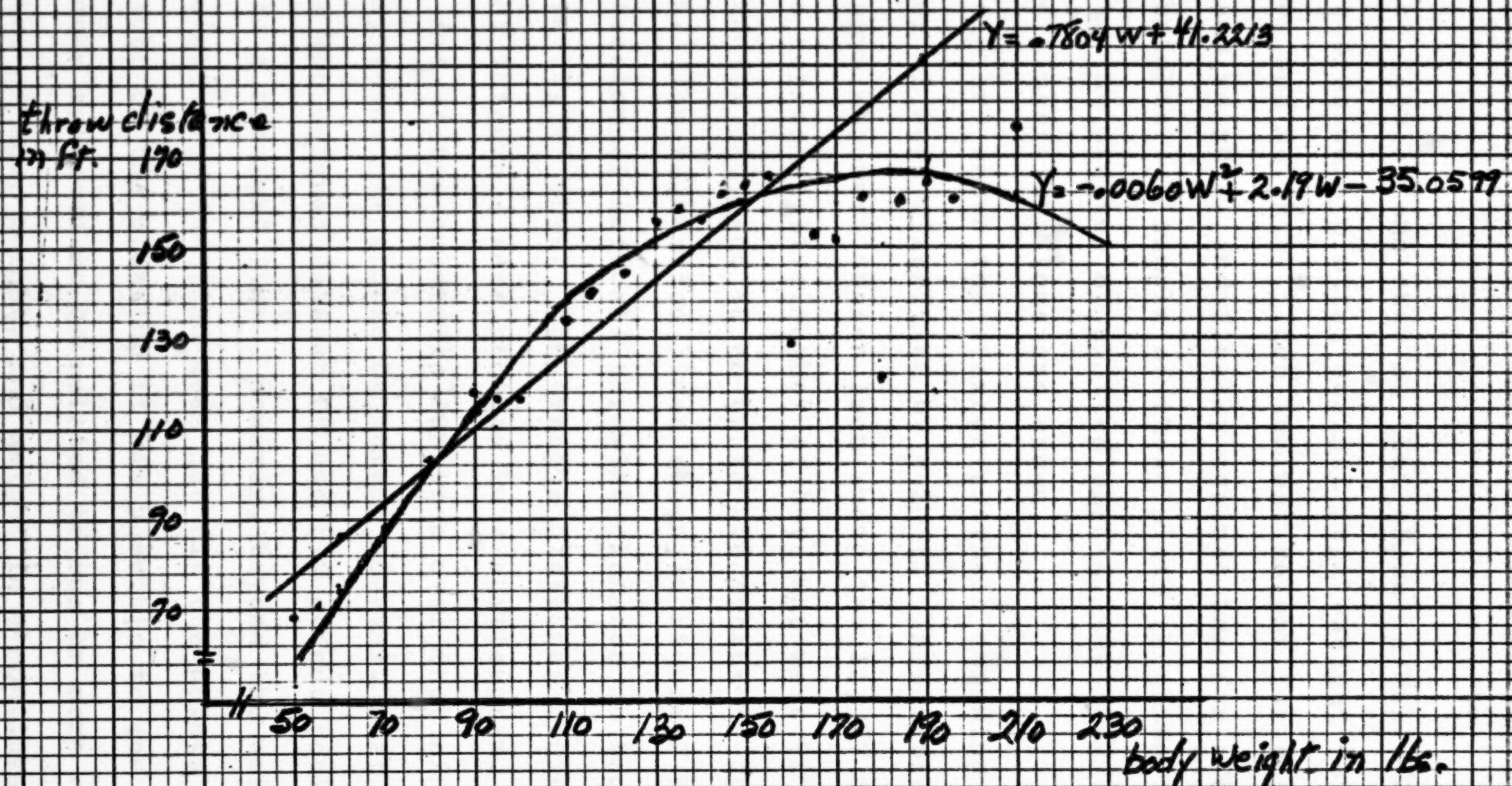

figure 2 Comparison of linear and quadratic regressions of boys Softball Throw by weight

10 Squares to the Inch
12-280

the number of individual students who were included in each of the cells of each cube. Total and average performance scores were calculated for the students in each cell. A sample of these is shown in Table 2.

Using the tabulations such as that shown in Table 2, the average performance scores were plotted against pupil-weight for each of a number of ages and heights. Then against height for each of a number of ages and weights, and finally against age for a number of weights and heights. A sample of these plots is shown in Figure 2. In addition to the scatter of plotted points, the best fitting quadratic and linear functions are shown.

In Table 2 are shown the average softball throwing distances and the number of boys classified by weight. This table was made up for 1727 boys who were chosen from among the 14,327 in such a manner that a representative number of boys who were 96 months, 108 months, 120 months old, and so on up to 216 months of age were chosen at random. The regression lines shown in Figure 2 were obtained from the regression of softball throwing distance on body weight for the entire 14,327 boys. The average distances achieved by the various weight intervals were plotted in a scattergram. The superiority of the fit of the quadratic function over that of the linear can be clearly seen. It should be noted, however, that the plotted dots for boys who weighed between 60 and 130 pounds could be fitted very easily to a straight line. However, beyond the weight of 130 pounds a straight line function does not fit the points at all well.

As a result of the plotting it was possible to see that some of the performances appeared to be related to one or more of the pupil characteristics of age, height, and weight in a nonlinear manner.

Table 2

Average Distances of Softball Throws Made by Boys Ages 9 through 15 Classified According to Weight

Weight Interval in Pounds	f	Average Distance of Throw -- Feet
47.5 - 52.49	1	68
52.5 - 57.49	18	71
57.5 - 62.49	70	75
62.5 - 67.49	126	82
67.5 - 72.49	135	88
72.5 - 77.49	112	99
77.5 - 82.49	104	104
82.5 - 87.49	98	112
87.5 - 92.49	107	118
92.5 - 97.49	99	117
97.5 - 102.49	78	117
102.5 - 107.49	59	130
107.5 - 112.49	46	134
112.5 - 117.49	64	140
117.5 - 122.49	75	144
122.5 - 127.49	86	144
127.5 - 132.49	94	156
132.5 - 137.49	92	158
137.5 - 142.49	56	156
142.5 - 147.49	59	163
147.5 - 152.49	37	165
152.5 - 157.49	28	166
157.5 - 162.49	19	129
162.5 - 167.49	17	153
167.5 - 172.49	13	152
172.5 - 177.49	7	162
177.5 - 182.49	4	122
182.5 - 187.49	11	161
187.5 - 192.49	3	165
192.5 - 197.49	4	161
Over 197.5	5	136

It was observed that each of the pupil characteristics (age, height, and weight) appeared to be related to all the performances in a similar manner. For example, pupil weight appeared to bear a similar relationship to each of the five performances. This relationship appeared to be expressible as either a second or third degree polynomial. The relationship of age to the five performance scores for males seemed to be expressible as a linear function. However, among the girls the performances seemed to be expressible as a quadratic function of their ages.

By observation of the average performance scores plotted by each of the characteristics of age, height, and weight, it was impossible to detect any indication of the presence of exponential, logrithmic or other complex nonlinear relationships among the data. The problem then resolved itself into that of determining which degree of polynomial most appropriately expressed the relationships between each of the pupil characteristics and each of the performances. Thus, the following null hypotheses could be stated for each of the pupil characteristics and each of the performances:

H_0 The time in seconds required for a pupil to run a 50-yard dash cannot be expressed as a linear function of his weight.

H_1 The time in seconds required for a pupil to run a 50-yard dash cannot be more effectively expressed as a quadratic function than as a linear function of his weight.

H_2 The time in seconds required for a pupil to run a 50-yard dash cannot be more effectively expressed as a cubic function than as a quadratic function of his weight.

The foregoing three null hypotheses are illustrative of those which were tested in this study. The tests of H_1 and H_2 required more rigorous standards than the conventional tests of statistical significance. The large numbers of degrees of freedom so reduced the denominators of the f-tests that the most inconsequential of differences yielded significant values of f. It was arbitrarily decided that to reject the hypotheses that the quadratic function was not more effective than the linear it was necessary that the quadratic regression account for at least one percent more of the sums of squares of variation of the dependent variables than was accounted for by the linear regression. This requirement resulted in subjecting the hypotheses to much more rigorous tests.

B. Testing Single Variable Hypotheses Among Males

1. Age as a Predictor of Physical Performances. The hypotheses concerning physical performances as a function of the age in months of boys which were tested were those associated with the linear, the quadratic and the cubic functions.

The linear functions may be expressed as:

$$\Sigma Y_p = a_p \Sigma(X_{1/100}) + Nk_p$$

Where:

Y_p = p^{th} physical performances (p = 1 --- 5)

N = 14,327 Male Students

a_p = Regression coefficient) Associated with p^{th} performance variables

k_p = Regression constant)

X_1 = Age of male pupils in months

The quadratic functions may be expressed as:

$$\Sigma Y_p = a\,\Sigma_p(X_{1/100})^2 + b\Sigma(X_{1/100}) + Nk_p$$

The cubic functions may be expressed as:

$$\Sigma Y_p = a\,\Sigma_p(X_{1/100})^3 + b\,\Sigma_p(X_{1/100})^2 + c\Sigma(X_{1/100}) + Nk_p$$

These three types of regression equations were obtained for each of the five performances using the least squares procedures. It will be noted that the age in months, height in inches, and weight in pounds of each student were each divided by 100 before the regression equations were developed. This was necessary to avoid exceeding the capacity of the IBM 7090 computer when the higher powers of these values were obtained.

The regression coefficients, sums of squares, and multiple correlations for each regression are shown in Tables 3, 4, and 5. The tests of the advantage of the quadratic regressions over the linear are shown in Table 6, and the tests of the advantage of the cubic over quadratic regressions are shown in Table 7.

Table 3

Values Obtained for Linear Regression of Each of Five Physical Performances on Age of 14,327 Male Pupils

Regression Value	Physical Performance (Dependent Variable) Y_1 Shuttle Run	 Y_2 Broad Jump	 Y_3 50-Yd.Dash	 Y_4 Softball Throw	 Y_5 600-Yd. Walk/Run
Regression Coefficient(a)	-2.53821	33.1541	-2.47307	109.023	-71.0709
Regression Constant(k)	14.9890	14.4757	11.8067	-43.1324	251.842
Regression Sums of Squares	5744.96	980,181.0	5453.87	10,599,100.0	4,504,180.0
Coefficient of Determination	.190529	.460991	.301255	.493628	.358056
R	-.4365	.6790	-.5489	.7026	-.5984

Table 4

Values Obtained for Quadratic Regression of Each of Five Physical Performances on Age of 14,327 Male Pupils

	Physical Performance (Dependent Variable)				
Regression Value	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd. Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient (a)	.745315	9.90480	.300840	5.65631	23.5807
(b)	-4.81221	2.93402	-3.39095	91.7657	-143.017
Regression Constant(k)	16.6768	36.9048	12.4880	-30.3242	305.240
Regression Sums of Squares	5783.17	987,017.0	5460.16	10,601,400.0	4,542,920.0
Coefficient of Determination	.1918	.4642	.3016	.4937	.3611
R	.4380	.6813	.5492	.7027	.6009

Table 5

Values Obtained for Cubic Regression of Each
of Five Physical Performances on Age of 14,327
Male Pupils

Regression Value	Physical Performance (Dependent Variable) Y_1 Shuttle Run	 Y_2 Broad Jump	 Y_3 50-Yd.Dash	 Y_4 Softball Throw	 Y_5 600-Yd. Walk/Run
Regression Coefficient (a)	1.42360	-3.68417	1.17384	-19.8724	33.4995
(b)	-5.49356	26.0503	-4.84344	92.7456	-123.229
(c)	4.08339	-20.0876	3.94397	-32.411	66.3096
Regression Constant(k)	12.5567	47.5688	9.09066	27.1931	208.288
Regression Sums of Squares	5888.60	987.669.0	5531.33	10,621,300	4,600,910.0
Coefficient of Determination	.1953	.4645	.3055	.4947	.3658
R	.4419	.6816	.5528	.7033	.6048

Table 6

Analyses of Linear and Quadratic Regressions of Physical Performances on Ages of the Pupils

Regression Analyses by Dependent Variables

		Y_1			Y_2			Y_3		
		Shuttle Run			Broad Jump			50-Yd. Dash		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Quad. Regression	2	5783.67	2891.83		987,017.0	493,508.5		5460.16	2730.08	
Linear Regression	1	5744.96	5744.96		980,181.0	980,181.0		5453.87	5453.87	
Difference	1	38.71	38.71	22.77	6,836.0	6,836.0	91.72	6.29	6.29	7.15
Quad. Resid.	14,324		1.7012			74.53			.8827	
Linear "	14,325		1.7039			80.00			.8831	
Total	14,326	30,152.70			2,126,250.0			18,103.8		

Table 6 (Continued)

		Y_4 Softball Throw			Y_5 600-Yd. Walk/Run		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Quad. Regression	2	10,601,400.0	5,300,700.0		4,542,920.0	2,271,460.0	
Linear Regression	1	10,599,100.0	10,599,100.0		4,504,180.0	4,504,180.0	
Difference	1	2,300.0	2,300.0	3.03	37,740.0	37,740.0	67.20
Quad. Resid.	14,324		758.9			561.6	
Linear "	14,325		759.0			563.7	
Total	14,326	21,417,900.0			12,579,500.0		

Table 7

Analyses of Quadratic and Cubic Regression of Physical Performances on Ages of Male Pupils

		Regression Analyses by Dependent Variables								
		Y_1			Y_2			Y_3		
		Shuttle Run			Broad Jump			50-Yd.Dash		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Cubic Regression	3	5888.60			987,669.0			5531.33		
Quad. Regression	2	5783.67			987,017.0			5460.16		
Difference	1	104.93	104.93	62.09	652.0	652.0	8.20	71.17	71.17	80.87
Cubic Residual	14,322		1.69			79.49			.8778	

Table 7 (Continued)

		Y_4 Softball Throw			Y_5 600-Yd. Walk/Run		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Qubic Regression	3	10,621,300.0			4,600,970.0		
Quad. Regression	2	10,601,400.0			4,542,920.0		
Difference	1	19,900.0	19,900.0	26.27	58,050.0	58,050.0	104.21
Cubic Residual	14,322		757.56			557.04	

With one exception the f-values obtained in testing the advantage of the quadratic over the linear function shown in Table 6, are highly significant. That one exception was for the prediction of softball throwing distance. With 1 and 1000 degrees of freedom an f of 6.66 is required at the .01 level of confidence. With one and an infinite number of degrees of freedom, an f of 6.64 is required at the .01 level of confidence. Similarly, the cubic regressions were shown in Table 7 to be significantly superior to the quadratic regressions. With this large a number of cases almost any difference can be shown to be statistically significant.

A more positive way to evaluate the importance of these differences is to compare the coefficients of determination for the various regression equations. The coefficients of determination were calculated by dividing the sums of squares for regression by the sums of squares for total variation. Thus, they are an expression of the portion of the variation of the dependent variable which can be accounted for by variation of the independent variables. By comparing the coefficients of determination shown in Tables 3, 4, and 5, it can be seen that in only two regressions, that for Y_1 (shuttle run) and Y_5 (600-yd. walk/run) did the cubic regression account for as much as one-half of one percent more of the variability than did the linear regressions. This is an example of an inconsequential difference which is statistically significant. It was decided that to take the analysis further would be fruitless. The effect of this decision was that the hypotheses designated as H_0, that physical performance scores could not be expressed as linear functions of pupil ages were rejected, the H_1 and H_2 hypotheses that pupil physical performance could not be more effectively expressed as quadratic or cubic functions of pupil age could not be rejected.

2. Height as Predictor of Physical Performance

The hypotheses concerning physical performance as a function of height were similarly stated in regression equations and tested in the manner described in the preceding section.

The analyses are shown in Tables 8, 9, 10, 11, and 12. Results which were similar to those reported for the predictions of physical performances on the basis of pupil ages were obtained. However, it was noted that in only two of the regression analyses did the quadratic show a significant advantage over the linear. These were: the prediction for Y_2(broad jump) and Y_5(600-yd. walk/run).

The advantage of the cubic regression over the quadratic was tested. This test is shown in Table 12. For each performance the cubic regression is shown to be significantly superior to the quadratic. Here again, a comparison of the coefficients of determination shown in Tables 8, 9, and 10 revealed that the advantages, although statistically significant were inconsequential. The cubic regressions each accounted for less than one-half of one percent more of the dependent variate veriability than did the linear regression. Here again the null hypotheses could only be rejected in so far as the linear function was concerned. The null hypotheses concerning the higher order functions could not be rejected on the basis of the evidence here presented.

Table 8

Values Obtained for Linear Regression of Each of Five Physical Performances on Height of 14,327 Male Pupils

Regression Value	Physical Performance (Dependent Variable)				
	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd.Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient (a)	-9.5160	137.721	-10.0492	480.509	-274.249
Regression Constant(k)	16.928	-19.1313	14.1755	-170.686	310.946
Regression Sums of Squares	4136.70	866,453.0	4613.24	10,547,400.0	3,435,850.0
Coefficient of Determination	.1372	.40750	.2548	.4912	.2731
R	-.3704	.6384	-.5048	.7009	-.5256

Table 9

Values Obtained for Quadratic Regression of Each of Five Physical Performances on Height of 14,327 Male Pupils

	Physical Performance (Dependent Variable)				
	Y_1	Y_2	Y_3	Y_4	Y_5
Regression Value	Shuttle Run	Broad Jump	50-Yd. Dash	Softball Throw	600-Yd. Walk/Run
Regression Coefficient (a)	4.28995	114.446	-1.03549	-37.7451	.211525
(b)	-14.8047	-3.36670	-8.77267	527.041	-535.017
Regression Constant(k)	18.5444	23.9866	13.7834	-184.907	390.640
Regression Sums of Squares	4140.85	869,398.0	4613.50	10,547,800.0	3,445,920.0
Coefficient of Determination	.1373	.4089	.2548	.4912	.2739
R	.3706	.6394	.5048	.7009	.5234

Table 10

Values Obtained for Cubic Regression of Each of Five Physical Performances on Height of 14,327 Male Pupils

Regression Value	Physical Performance (Dependent Variable) Y_1 Shuttle Run	 Y_2 Broad Jump	 Y_3 50-Yd. Dash	 Y_4 Softball Throw	 Y_5 600-Yd. Walk/Run
Regression Coefficient (a)	26.9669	-213.062	32.8247	-992.172	519.938
(b)	-40.2561	466.396	-55.2581	1601.20	-647.359
(c)	9.15479	-192.668	20.3915	-354.484	-73.0664
Regression Constant(k)	14.3684	56.9814	8.70227	-31.2619	310.130
Regression Sums of Squares	4172.43	871,357.0	4660.26	10,590.500.0	3,457,870.0
Coefficient of Determination	.1384	.4098	.2574	.4932	.2749
R	.3720	.6402	.5074	.7023	.5243

Table 11

Analyses of Linear and Quadratic Regressions of Physical Performances on Ages of the Pupils

		Regression Analyses by Dependent Variables								
		Y_1 Shuttle Run			Y_2 Broad Jump			Y_3 50-Yd. Dash		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Quad. Regression	2	4140.85	2070.43		869,398.0	434,699.0		4613.50	2306.75	
Linear Regression	1	4136.70	4136.70		866,453.0	866,453.0		4613.24	4613.24	
Difference	1	4.15	4.15	2.27	2,945.0	2,945.0	33.51	.26	.26	
Quad. Resid.	14,324		1.82			87.74			.94	
Linear "			1.81			87.94			.94	
Total	14,326	30,152.7			2,126,250.0			18,103.8		

Table 11 (Continued)

Source of Variation	df	Y_4 Softball Throw			Y_5 600-Yd. Walk/Run		
		Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Quad. Regression	2	10,547,800.0	5,273,900.0		3,445,920.0	1,722,960.0	
Linear Regression	1	10,547,400.0	10,547,400.0		3,435,850.0		
Difference	1	400.0	400.0	f <1	10,070.0	10,070.0	15.79
Quad. Residual	14,324		762.64			637.64	
Linear Residual			726.64			638.32	
Total	14,326	21,417,900.0			12,579,500.0		

Table 12

Analyses of Quadratic and Cubic Regressions of Physical Performances on Height of Male Pupils

		Regression Analyses by Dependent Variables								
		Y_1			Y_2			Y_3		
		Shuttle Run			Broad Jump			50-Yd.Dash		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Cubic Regression	3	4172.43			871,357.0			4660.26		
Quad. Regression	2	4140.85			869,398.0			4613.50		
Difference	1	31.48	31.48	17.39	1,959.0	1,959.0	22.45	46.76	46.76	49.96
Cubic Residuals	14,323		1.81			87.25			.94	

Table 12 (Continued)

Source of Variation	df	Y_4 Softball Throw Sum Squ.	Mean Squ.	f	Y_5 600-Yd. Walk/Run Sum Squ.	Mean Squ.	f
Cubic Regression	3	10,590,500.0			3,457,870.0		
Quad. Regression	2	10,547,800.0			3,445,920.0		
Difference	1	42,700.0	42,700.0	56.18	119,500.0	11,950.0	18.76
Cubic Residuals	14,323		759.71			636.85	

3. Weight as a Predictor of Physical Performance

The hypotheses concerning physical performances as functions of the weight in pounds of male pupils were tested in a manner similar to that used in the preceding analyses. The values for the linear and quadratic functions were calculated. They are shown in Tables 13, 14, and 15. However, the magnitude of the coefficients of determination shown in Tables 14 and 15 makes it unnecessary to test them for significance. A comparison of the coefficients of determination in Table 15 with those in Table 14 will reveal that the quadratic regression of physical performance on weight accounted for from 3 percent to 5 percent more of the variability of the dependent variates than did the linear regression. The regressions of the physical performances as cubic functions of weight were not tested. The plots of weight against the performances when age and height were held constant suggested that the performances might be an 8th order polynomial function of pupil weights. Therefore, an 8th order polynomial regression of each of the five performances was calculated. The regression sums of squares, coefficients of determination and indexes of correlation for these regressions are shown in Table 15. The coefficients of determination are no larger than those shown in Table 14. In fact those for the shuttle run and softball throw performances are slightly smaller. This indicates that any advantage of predictability with the higher order function was more than offset by the loss due to the roundings of the higher order values. It was concluded that the use of higher order functions would give no further advantage over the regression of physical performances as quadratic

Table 13

Values Obtained for Linear Regression of Each of Five Physical Performances on Weight of 14,327 Male Pupils

Regression Value	Physical Performance (Dependent Variables)				
	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd.Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient(a)	-1.27125	19.2328	-1.37471	78.0386	-32.9822
Regression Constant(k)	12.4347	44.9963	9.46524	41.2214	177.492
Coefficient of Determination	.0749	.2430	.1458	.3961	.1208
R	-.2736	.4929	-.3818	.6294	-.3475

Table 14

Values Obtained for Quadratic Regression of Each of Five Physical Performances on Weight of 14,327 Male Pupils

Regression Value			Physical Performance (Dependent Variables)		
	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd.Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient (a)	4.78874	-20.2927	1.79350	-59.8820	51.2834
(b)	-5.47368	66.9081	-5.58834	218.725	-153.467
Regression Constant(k)	14.7133	19.1462	11.7499	-35.0599	242.820
Coefficient of Determination	.1002	.2893	.1883	.4361	.1708
R	.3166	.5379	.4339	.6603	.4132

Table 15

Values Obtained for the Regression of Each of Five Physical Performances on the 8th Power of the Weight of 14,327 Male Pupils
(Regression Coefficients and Constants are not Shown)

Regression Value	Physical Performance (Dependent Variables)				
	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd. Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Sums of Squares	2871.61	622,336.0	3323.73	9,323,020.0	2,189,920.0
Coefficient of Determination	.0952	.2927	.1836	.4342	.1741
Index of Correlation	.3086	.5410	.4285	.6589	.4142

functions of weight. In view of the preceding analyses, which showed fractional percents of difference in favor of the quadratic regressions to be highly significant, it appeared that a test of significance of such large differences as found here would be superfluous. Therefore, it must be concluded that the physical performance scores achieved by the male pupils in this study may best be expressed as quadratic functions of the body weight of the pupils.

C. Testing Multiple Variable Regression Hypotheses Among Male Pupils

In preceding sections of this report, it has been shown that the physical performances of boys expressed as scores on the items of the AAHPER Youth Fitness Test could be satisfactorily expressed as linear functions of pupil ages and heights, and as quadratic functions of pupil weights. The hypotheses to be tested in this section is that the combination of these functions expressed as in the following equation:

$$\Sigma Y_p = a\Sigma(X_1/100) + b\Sigma(X_2/100) + c\Sigma(X_2/100)^2 + d\Sigma(X_2/100) + Nk$$

where:

X_1 = Pupil age in months

X_2 = Pupil height in inches

X_3 = Pupil weight in pounds

Y_p = Item performance score on AAHPER test ($p = 1$ --- 5)

N = 14,327 male pupils

and a, b, c, d, and k are appropriate coefficients and constants is not significantly superior to all possible combinations of fewer variables.

1. Four Factor Multiple-nonlinear Regression of Physical Performance Scores

The values for the four variable, multiple nonlinear regression equations are shown in Table 16. From the magnitude of the indexes of multiple correlation, it can be seen that these regressions would be highly significant statistically. It was decided that an actual test of this significance would be superfluous.

The corresponding values for each of the regressions with fewer variables are shown in Tables 17, 18, and 19. The regression analysis to evaluate the contribution of each of the pupil characteristics to the multiple nonlinear regression is shown in Table 20. The Multiple Indexes of Correlation shown in Table 16 ranged from .45 for the relationship with the shuttle run (Y_1) performance scores, to .74 for the relationship with the softball throwing performance score.

2. Regression of Physical Performance Scores on Fewer than Three Pupil Characteristics

The predictive effectiveness of the complex regression equation is indicated by the coefficients of determination. The coefficients of determination shown in Table 16, indicate that 20 percent of the total sums of the squared variations of pupil performance in the shuttle run could be accounted for by differences among the pupils in age, height, and weight. This was the least portion so accounted for. Nearly one-half of the variability in broad jumping performance was accounted for by differences among pupils on the three characteristics and over one-half of the variability in softball throwing performance could be so accounted for.

Table 16

Values for Four-Variable Nonlinear Regression of Physical Performances of Male Pupils

Regression Value	Physical Performance (Dependent Variable)				
	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd. Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient					
(a)	-2.44807	24.4665	-1.92158	57.7881	-66.8677
(b)	-4.79605	95.1467	-6.44896	205.824	-225.012
(c)	.129742	.932022	.227236	-11.6105	-3.27878
(d)	.588289	-11.8493	.203156	39.9821	48.2976
Regression Constant(k)	17.0062	-19.1151	14.4222	-119.286	336.005
Sums of Squares for Regression	6095.68	1,057,950.0	5880.60	11,687,000.0	5,146,660.0
Coefficient of Determination	.2022	.4976	.3248	.5443	.4091
Multiple Index of Correlation	.4496	.7054	.5699	.7378	.6396
Standard Error of Estimate	1.296	8.637	.9238	26.1382	22.7812

Table 17

Values for Regression of Physical Performances As Linear Functions of Height and Quadratic Functions of Weight

	Physical Performance (Dependent Variable)				
Regression Value	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd. Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient					
(b)	-11.5722	162.869	-11.7678	365.779	-410.099
(c)	.650391	-4.27144	.635913	-23.9007	10.9425
(d)	-1.01948	4.21906	-1.05884	77.9344	4.38234
Regression Constant(k)	18.4745	-33.7889	15.5747	-153.944	376.109
Sums of Squares for Regression	4405.90	889,170.0	4839.48	10,745,400.0	3,885,950.0
Coefficient of Determination	.1461	.4182	.2673	.5004	.3089
Multiple Index of Correlation	.3823	.6467	.5170	.7074	.5558

Table 18

Values for Regression of Physical Performances as Linear Functions of Age and Quadratic Functions of Weight

Regression Value	Physical Performance (Dependent Variable)				
	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd. Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient (a)	-2.82791	32.0019	-2.43233	74.0889	-84.6881
(b)	.417319	-4.77308	.613923	-23.9519	10.2132
(d)	-.603597	11.7960	-1.39950	91.1322	-7.62093
Regression Constant(k)	15.5614	9.54941	12.4793	-57.2780	268.217
Sums of Squares for Regression	5910.11	984,919.0	5545.09	11,345,200.0	4,738,210.0
Coefficient of Determination	.1960	.4632	.3063	.5284	.3767
Multiple Index of Correlation	.4427	.6806	.5534	.7269	.6137

Table 19

Values for Regression of Physical Performances as Multiple Linear Functions of Age and Height

	Physical Performance (Dependent Variable)				
	Y_1	Y_2	Y_3	Y_4	Y_5
Regression Value	Shuttle Run	Broad Jump	50-Yd.Dash	Softball Throw	600-Yd. Walk/Run
Regression Coefficient (a)	-2.34880	23.1476	-1.85228	60.6132	-61.3920
(b)	-1.02246	54.0164	-3.35112	261.324	-52.2481
Regression Constant(k)	15.3263	-3.34603	12.9124	-129.352	269.080
Sums of Squares for Regression	5760.73	1,024,180.0	5623.22	11,629,000.0	4,545,350.0
Coefficient of Determination	.1911	.4817	.3106	.5416	.3613
Multiple Index of Correlation	.4371	.6940	.5573	.7359	.6011

Table 20

Regression Analyses to Evaluate Contribution of Pupils Ages, Heights, and Weights to Multiple Nonlinear Regressions of Physical Performances of Male Pupils

		Y_1			Y_2			Y_3		
		Shuttle Run			Broad Jump			50-Yd. Dash		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
1) Mult. Nonlin. 4 fact. regr.	4	6,095.68			1,057,950.0			5,880.60		
2) 3 fact. (less age)	3	4,405.90			889,170.0			4,839.48		
3) 3 fact. (less height)	3	5,910.11			984,919.0			5,545.09		
4) 2 fact. (less weight)	2	5,760.73			1,024,180.0			5,623.22		
Differences										
5) 1 - 2	1	1,689.78	1,689.78	1,006	168,780.0	168,780.0	2,261	1,041.12	1,041.12	1225
6) 1 - 3	1	185.57	185.57	110	73,031.0	73,031.0	979	334.51	334.51	394
7) 1 - 4	2	334.95	167.47	99.7	33,770.0	16,885.0	226	257.38	128.69	151
Four Variab. 8) Residuals	14,322	25,057.02	1.68		1,068,300.0	74.59		12,223.20	.85	
9) Total	14,326	30,152.7			2,126,250.0			18,103.8		
Partial Corr.										
10) $R_{Y_p X_1 \cdot X_2 X_3^2}$		.2511	-		.3693	-		.2801	-	
11) $R_{Y_p X_2 \cdot X_1 X_3^2}$		.0854	-		.2527	-		.1631	-	
12) $R_{Y_p X_3^2 \cdot X_1 X_2}$		.1144	-		.1749	-		.1443	-	

Table 20 (Continued)

Source of Variation	df	Y_4 Softball Throw Sum Squ.	Y_4 Softball Throw Mean Squ.	Y_4 Softball Throw f	Y_5 600-Yd. Walk/Run Sum Squ.	Y_5 600-Yd. Walk/Run Mean Squ.	Y_5 600-Yd. Walk/Run f
1) Mult. Nonlin. 4 fact. regr.	4	11,687,000.0			5,146,660.0		
2) 3 fact. (less age)	3	10,745,400.0			3,885,950.0		
3) 3 fact. (less height)	3	11,345,200.0			473,821.0		
4) 2 fact. (less weight)	2	11,629,000.0			4,545,350.0		
Differences							
5) 1 - 2	1	941,600.0	941,600.0	1412	1,260,710.0	1,260,710.0	2400
6) 1 - 3	1	341,800.0	341,800.0	513	408,450.0	408,450.0	784
7) 1 - 4	2	58,000.0	29,000.0	44	601,310.0	300,655.0	577
Four Variab. 8) Residuals	14,322	9,784,900.0	683.21		743,824.0	518.98	
9) Total	14,326	21,471,900.0			12,579,500.0		
Partial Corr.							
10) $R_{Y_p X_1 \cdot X_2 X_3^2}$		.2963	-		.3807	-	
11) $R_{Y_p X_2 \cdot X_1 X_3^2}$		.1846	-		.2280	-	
12) $R_{Y_p X_3^2 \cdot X_1 X_2}$		.0767	-		.2733	-	

The contribution of each of the pupil characteristics of age, height, and weight to the overall regression system is measured and evaluated in Table 20. In Table 20, line 1 of the table is devoted to showing the sum of squares of the variations of each of the physical performance score arrays which can be accounted for by the multiple (4 factor) nonlinear regression. In lines 2, 3, and 4 are shown the sums of squares accounted for by the regression equations which were developed without age(X_1), height(X_2) and weight(X_3), respectively. The differences in sums of squares between the four factor, and each of the lesser regression equations are shown in the 5th, 6th, and 7th lines of the table. These were tested for significance by application of the conventional f-test in which the mean square for the four factor residuals was used as the denominator of the f-ratio. The resulting f-values were all many times larger than that required for significance at the .01 level of confidence ($f \leq 6.64$). Here again, the shear numbers of cases involved in this study (14,327) would cause even an infinitesimal, inconsequential difference to be statistically significant. The relative practical importance of each of the pupil characteristics for predicting each of the physical performances has been determined in the third part of Table 20. This shows the various partial correlation coefficients. In line 10 of Table 20 are shown the partial correlation coefficients between each of the performance scores and pupil age with height, and weight held constant. Thus, the correlation between age in months and time in seconds required to complete the 600-yd. walk/run, by male pupils who are equal in height, and weight is .3807.

It is of interest to note that with each performance age is the largest contributor to the regression. Its relationship to performance varies from .25 with the shuttle run(Y_1) to .38 with the 600-yd. walk/run. The relationships of pupil height to the performances with age and weight held constant are shown in line 11 of Table 20. It can be seen that pupil height makes its least contribution to the regression of the shuttle run(Y_1) scores and its greatest contribution to the regression of the broad jump(Y_2) scores. The relationships between the quadratic function of pupil weight and the performances with height and age held constant are shown in line 12. It can be seen that with the exception of the regression of shuttle run(Y_1) scores and of the 600-yd. walk/run(Y_5) scores, pupil weight is the least important of the three factors for predicting physical performances. Its greatest contribution was to the regression of the 600-yd. walk/run scores wherein its partial correlation was a substantial .2733. Its least contribution was to the regression of the softball throw(Y_4) scores wherein its partial correlation was .0767. However, the quadratic expression of pupil weight did make a substantial and unique contribution to the regression of each of the physical performances other than the softball throw.

3. Summary of Multiple Regression Analysis Findings

It was found that the four-variable multiple nonlinear regression was significantly and substantially superior to any combination of fewer variables and or simpler functions. It was necessary, therefore, to reject the null hypothesis that the more complex functions had no advantage over the less complex functions.

It was also found that the five physical performances varied in the degree to which they were related to the combination of the three pupil characteristics. With the shuttle run being the least closely related and the softball throw being the most closely related to the three characteristics. As an illustration of the operation of the complex, nonlinear regression equations, the following example is presented:

The regression equation which was obtained for the prediction of boys softball throwing performances may be obtained from Table 16. It was:

$$57.7881\left(\frac{\text{age in months}}{100}\right) + 205.824\left(\frac{\text{height in inches}}{100}\right)$$

$$- 11.6105\left(\frac{\text{weight}}{100}\right)^2 + 39.9821\left(\frac{\text{weight}}{100}\right) - 119.286 = \begin{array}{l}\text{softball}\\ \text{throwing}\\ \text{distance}\\ \text{in feet}\end{array}$$

The foregoing equation may be simplified to:

$$.5779 \text{ age} + 2.058 \text{ height} - .0012 \text{ weight}^2 + .3998 \text{ weight}$$
$$- 119.286 = \text{softball throw in feet}$$

This equation represents a multi-dimensional function which would require four orthogonal axes for plotting. However, the three-dimensional frequency distribution represented in the data cube which was mentioned earlier, can be used to allow a two- and three-dimensional plotting of the function. For example, consider the cube shown in Figure 1. In this cube the horizontal section which contains the X-bearing blocks contains boys who are all of the same weight classification. If their weights are taken as the midpoint of this interval the factor of age for this group becomes a constant.

Table 21

Distributions of the Weights and Average Softball Throwing Distances of Four Groups of Boys who were 169 Months of Age and 60 Inches, 62 Inches, 64 Inches, and 66 Inches Tall

	Height Categories of Boys							
	60 Inches		62 Inches		64 Inches		66 Inches	
Weight Interval	N	Average Throwing Distance	N	Average Throwing Distance	N	Average Throwing Distance	N	Average Throwing Distance
75 - 84.9	5	111.4	1	111.0	1	114.0		
85 - 94.9	34	128.8	11	126.3	2	150.5		
95 - 104.9	43	132.8	65	131.5	32	129.4		
105 - 114.9	18	130.3	73	139.1	75	146.8	7	154.0
115 - 124.9	8	121.0	27	136.8	51	152.3	22	144.2
125 - 134.9	5	129.2	14	130.6	38	147.7	50	158.6
135 - 144.9	3	126.7	9	123.3	21	141.8	61	154.8
145 - 154.9			5	144.8	9	132.2	28	173.3
155 - 164.9			1	187.0	11	132.8	29	170.2
165 - 174.9			1	138.0	2	110.0	12	157.5
175 - 184.9	1	119.0	1	105.0	2	141.0	3	159.0
185 - 194.9					1	115.0	2	151.0
195 - 204.9							1	164.0
205 - 214.9								
215 - 224.9							3	132.0
225 - 234.9								

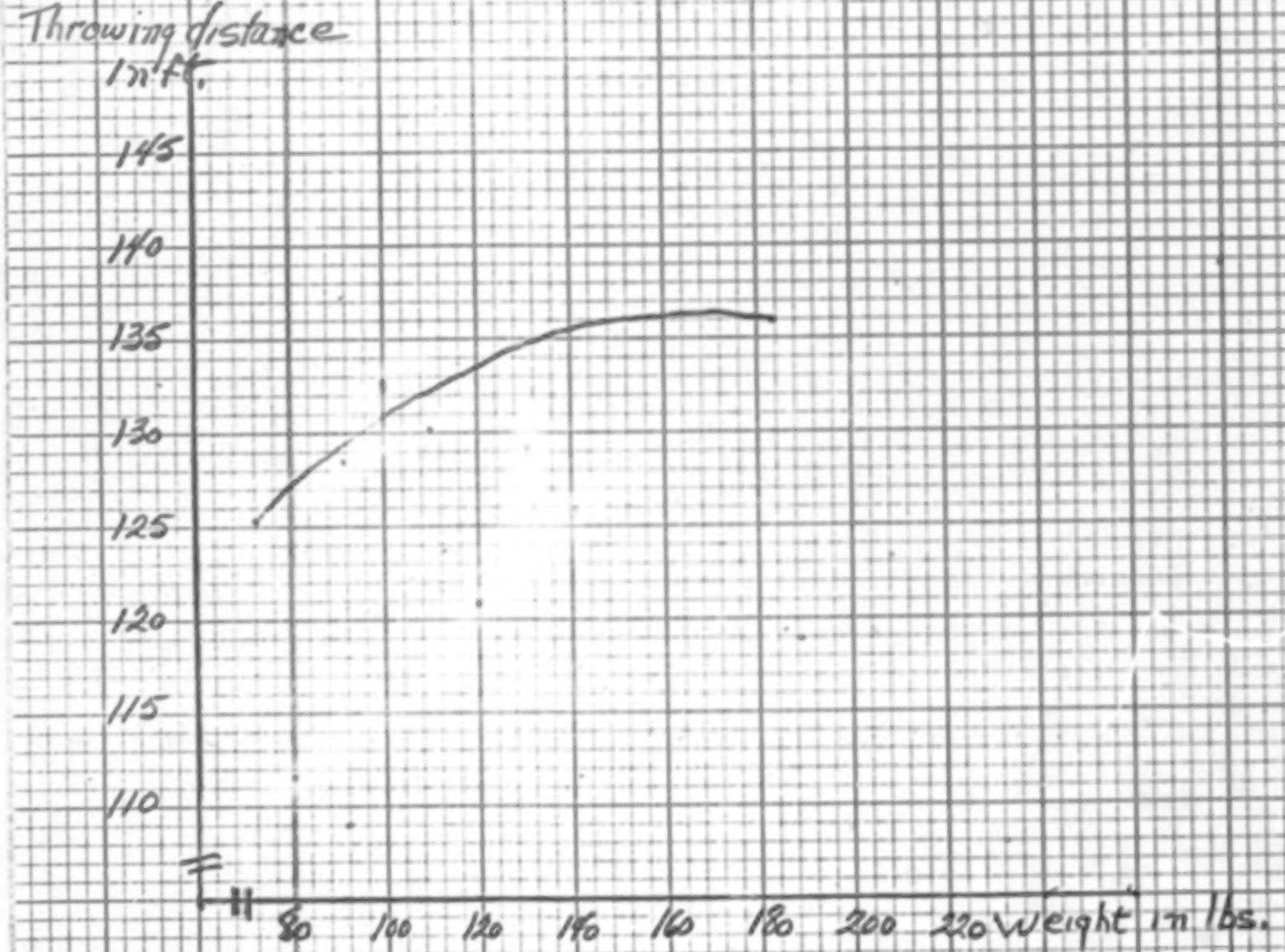

Figure 3. Plot of Softball Throw distance of Boys 60 inches tall and 169 months old By Their weight in lbs.

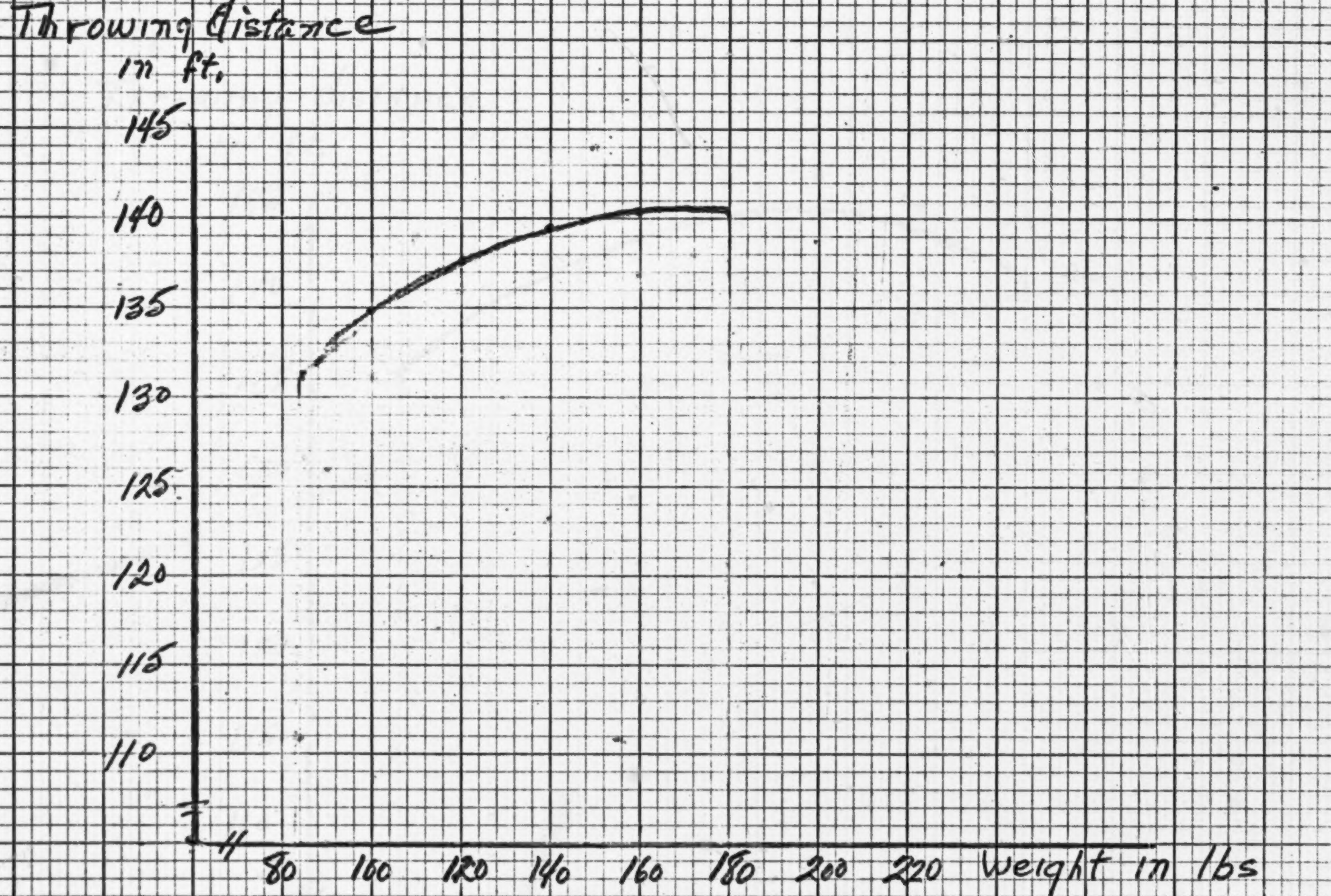

Figure 4. Plot of Softball Throwdistance of boys 62 inches tall and 169 months old by their Weights in lbs

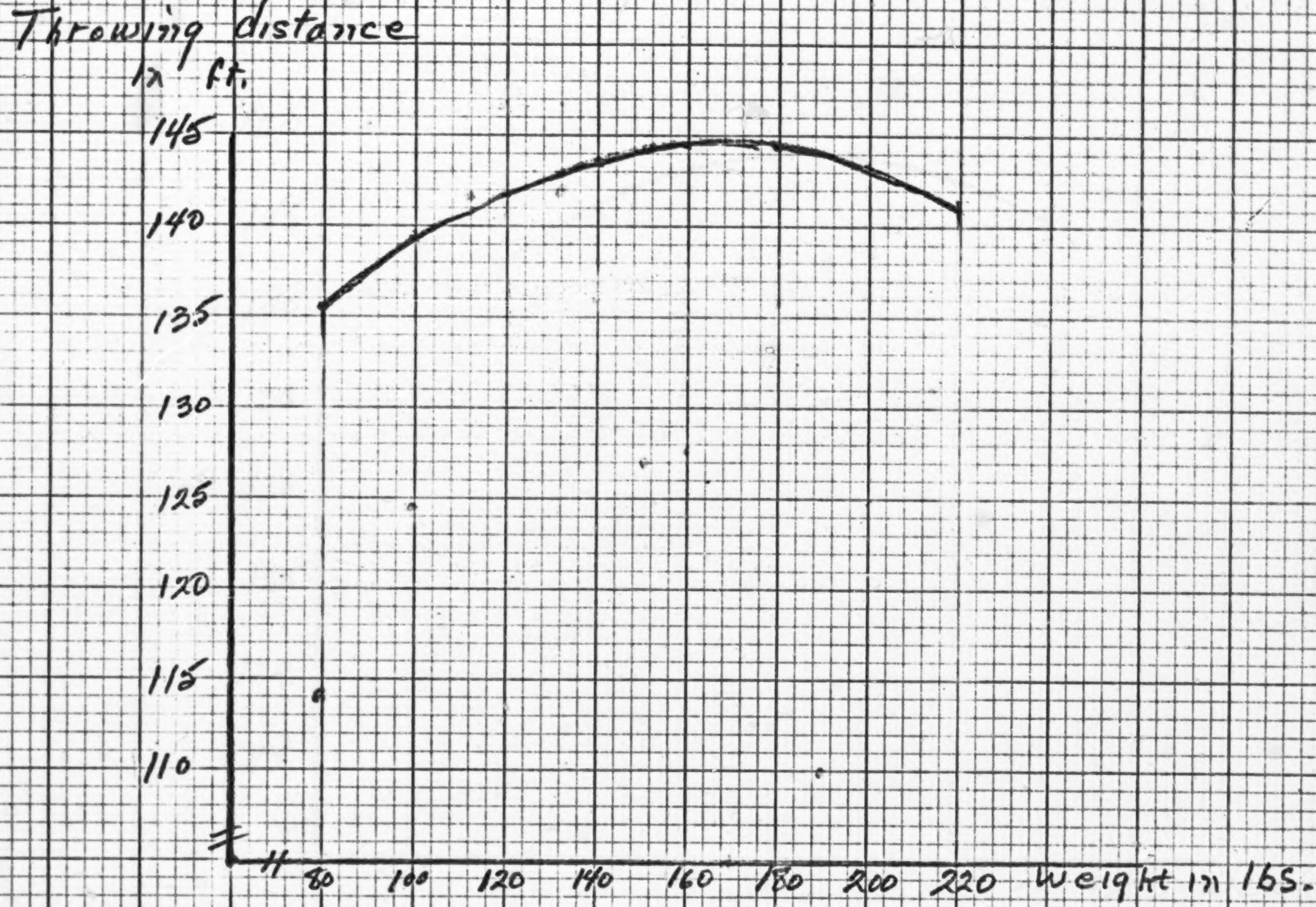

Figure 5 Plot of Softball Throw distance of boys 64 inches tall and 169 Months old by Their Weights in lbs.

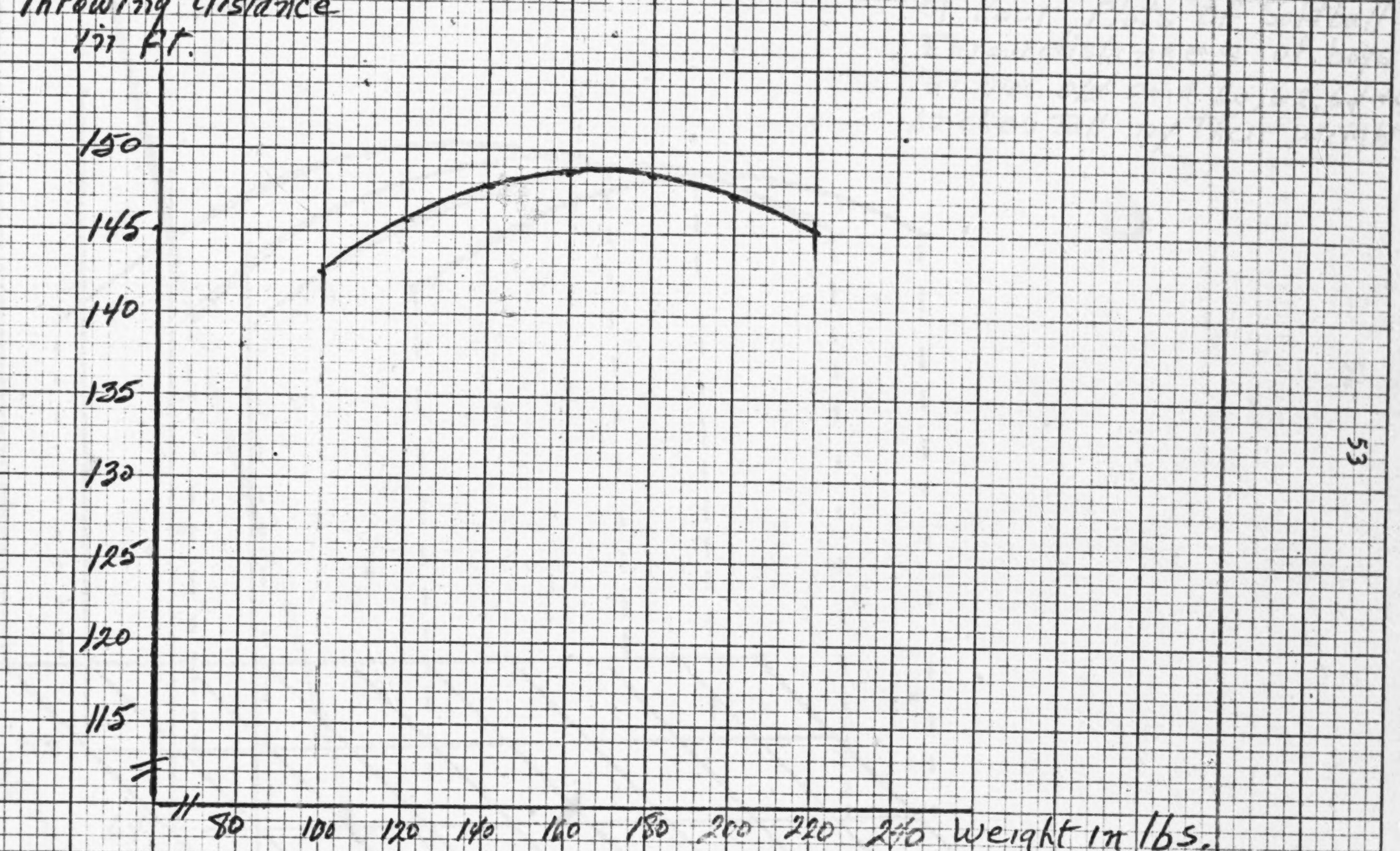

Figure 6 Plot of Softball Throw distance of boys 66 Inches tall 169 Months old by Their Weights in lbs.

uares to the inch

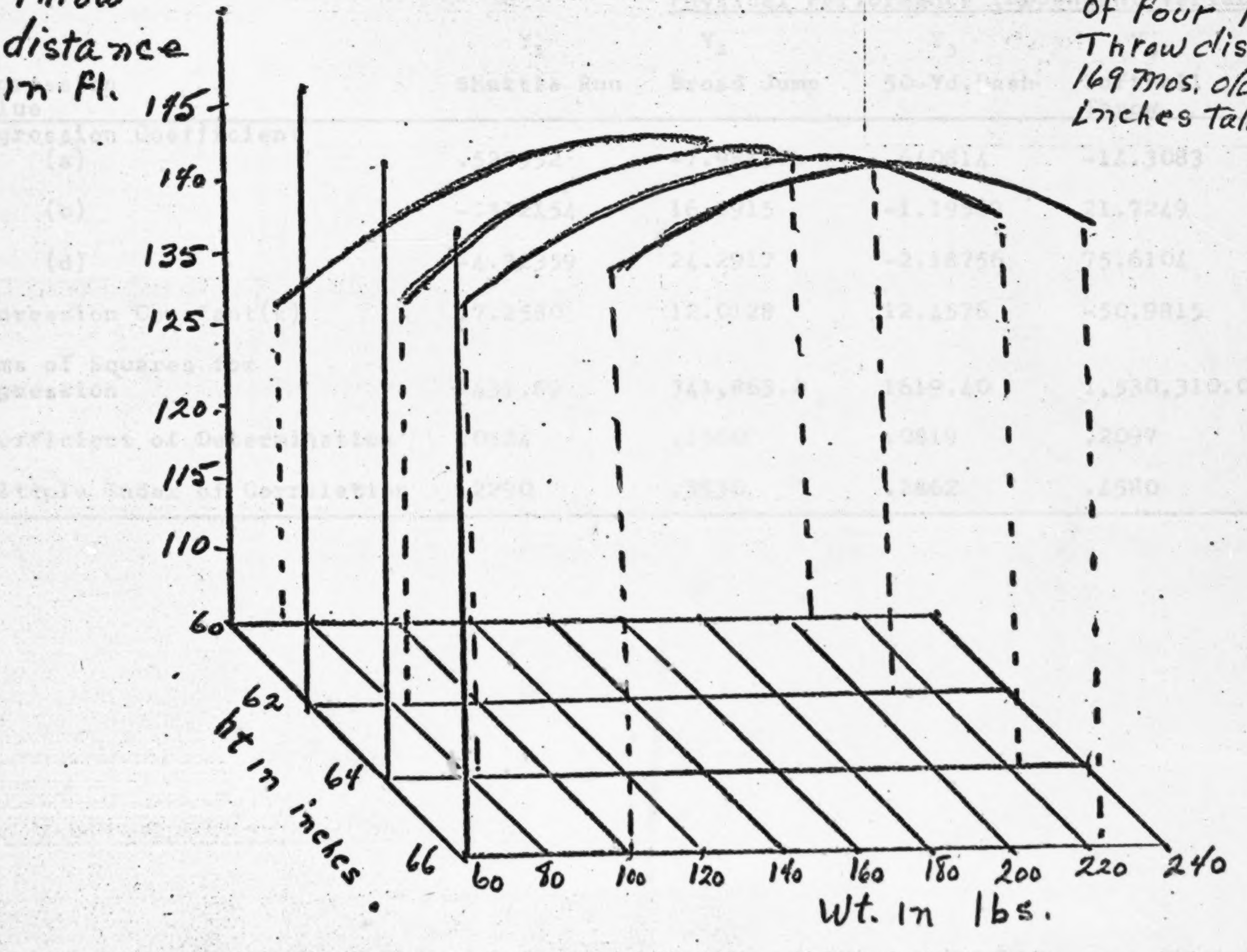

Figure 7 Perspective Composite of Four Plots of Softball Throw distances of boys 169 mos. old and 60, 62, 64 + 66 Inches tall by Their weights

Table 22

Values Obtained for Cubic Regression of Each of Five Physical Performances Scores on Age in Months of 14,486 Female Pupils

	Physical Performance (Dependent Variable)				
	Y_1	Y_2	Y_3	Y_4	Y_5
Regression Value	Shuttle Run	Broad Jump	50-Yd.Dash	Softball Throw	600-Yd. Walk/Run
Regression Coefficient					
(a)	.520952	-7.98437	.640814	-14.3083	9.52332
(c)	-.312454	16.8915	-1.19569	21.7249	-1.42480
(d)	-4.32359	24.2917	-2.18756	75.6104	-86.8955
Regression Constant(k)	17.2580	12.0128	12.4576	-50.9815	274.474
Sums of Squares for Regression	2431.89	341,863.0	1619.40	1,530,310.0	596,636.0
Coefficient of Determination	.0524	.1560	.0819	.2097	.0443
Multiple Index of Correlation	.2290	.3950	.2862	.4580	.2104

Table 23

Values Obtained for Quadratic Regression of Each of Five Physical Performances Scores on Age in Months of 14,486 Female Pupils

	Physical Performance (Dependent Variable)				
	Y_1	Y_2	Y_3	Y_4	Y_5
Regression Value	Shuttle Run	Broad Jump	50-Yd.Dash	Softball Throw	600-Yd. Walk/Run
Regression Coefficient					
(b)	2.04329	-19.2136	1.70206	-429,774.0	41.6395
(c)	-7.79854	77.5500	-6.46198	171.051	-150.419
Regression Constant(k)	18.9276	-13.5750	14.5112	-96.8351	305.267
Sums of Squares for Regression	2420.52	339,194.0	1602.18	1,521,700.0	592,832.0
Coefficient of Determination	.0522	.1548	.0810	.2085	.0440
Multiple Index of Correlation	.2284	.3934	.2847	.4567	.2097

Table 24

Values Obtained for Linear Regression of Each of Five Physical Performances Scores on Age in Months of 14,486 Female Pupils

	Physical Performance (Dependent Variable)				
	Y_1	Y_2	Y_3	Y_4	Y_5
Regression Value	Shuttle Run	Broad Jump	50-Yd.Dash	Softball Throw	600-Yd. Walk/Run
Regression Coefficient (c)	-1.53581	18.6598	-1.24513	39.3248	-22.7931
Regression Constant(k)	14.2557	30.3563	10.6195	1.43122	210.060
Sums of Squares for Regression	2114.46	312,131.0	1389.80	1,386,300.0	465,725.0
Coefficient of Determination	.0456	.1424	.0729	.1900	.0346
Multiple Index of Correlation	-.2135	.3774	-.2651	.4359	.1859

Table 25

Analyses of Cubic and Quadratic Regression of Physical Performances on Ages of Female Pupils

		Regression Analyses by Dependent Variables								
		Y_1 Shuttle Run			Y_2 Broad Jump			Y_3 50-Yd. Dash		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Cubic Regression	3	2431.89			341,863.0			1619.40		
Quad. Regression	2	2420.52			339,194.0			1602.18		
Difference	1	11.37	11.31	3.72	2669.0	2669.0	20.90	17.22	17.22	13.76
Cubic Resid.	14,484		3.04			127.72			1.25	
Total	14,486	46,390.2			2,191,500.0			19,771.7		

Table 25 (Continued)

Source of Variation	df	Y_4 Softball Throw Sum Squ.	Mean Squ.	f	Y_5 600-Yd. Walk/Run Sum Squ.	Mean Squ.	f
Cubic Regression	3	1,530,310.0			596,636.0		
Quad. Regression	2	1,521,700.0			592,832.0		
Difference	1	8,610.0	8,610.0	21.63	3,804.0	3,804.0	4.28
Cubic Resid.	14,484		398.15			889.30	
Total	14,486		7,296,290.0			13,475,600.0	

Table 26

Analyses of Quadratic and Linear Regressions of Physical Performances on Ages of Female Pupils

		Regression Analyses by Dependent Variables								
		Y_1 Shuttle Run			Y_2 Broad Jump			Y_3 50-Yd. Dash		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Quad. Regression	2	2420.52			339,194.0			1602.18		
Linear Regression	1	2114.46			312,131.0			1389.80		
Difference	1	306.06	306.06	100.68	27,063.0	27,063.0	211.59	212.38	212.38	169.90
Quad. Resid.	14,484		3.04			127.90			1.25	
Total	14,486	46,390.2			2,191,500.0			19,771.7		

Table 26 (Continued)

Source of Variation	df	Y$_4$ Softball Throw Sum Squ.	Y$_4$ Softball Throw Mean Squ.	Y$_4$ Softball Throw f	Y$_5$ 600-Yd. Walk/Run Sum Squ.	Y$_5$ 600-Yd. Walk/Run Mean Squ.	Y$_5$ 600-Yd. Walk/Run f
Quad. Regression	2	1,521,700.0			592,832.0		
Linear Regression	1	1,386,300.0			465,725.0		
Difference	1	135,400.0	135,400.0	339.59	127,107.0	127,107.0	142.89
Quad. Resid.	14,484		398.72			889.51	
Total	14,486	7,296,290.0			13,475,600.0		

Thus, for all boys whose age is no less than 168 months but not 170 months, the midpoint of the age interval 169 months can be taken as representative. Among these boys, age is not a variable and the regression equation becomes:

$$2.058 \text{ height} - .0012 \text{ weight}^2 + .3998 - 21.621 = \text{softball throw in feet}$$

Similarly, the group of boys whose ages were between 168 and 170 months were classified into height categories. Four of the categories obtained are shown in Table 21. This table shows the frequency distribution of pupil weights within each category and the average softball throw distance achieved by the pupils in each weight interval.

When the complex regression equation is applied to the students shown in Table 21, height is constant at 60 inches, and for those students the equation can be reduced to:

$$-.0012 \text{ weight}^2 + .3998 \text{ weight} + 102.888 = \text{softball throw in feet}$$

When the appropriate equations are applied to the data from Table 21, and the results graphed, the resulting graphs of the function may be aligned to yield a three-dimensional depiction. This is shown in Figures 3, 4, 5, 6, and 7. The result of this procedure is to obtain a graphic representation of softball throwing distance as a quadratic function of pupil weight with age and height accounted for and held constant. Using this principle, the computer can be programmed to generate norm tables for the performance levels achieved by boys of various ages, heights and weights.

D. Testing Single Variable Hypotheses Among Females

1. Age as a Predictor of Physical Performances

The hypotheses concerning the degree and kind of relationship between age in months of female pupils and their performance scores in the AAHPER test were tested in a manner similar to that employed with the scores of the male pupils. The values obtained for the cubic, quadratic, and linear regression equations are shown in Tables 22, 23, and 24, respectively.

The three regressions were compared. The comparison of the cubic and quadratic regressions of physical performance on the age of female pupils are shown in Table 25. The comparisons of the quadratic and linear regressions are shown in Table 26. The differences between the cubic and quadratic regression sums of squares, as shown in Table 25 are quite small, considering that over 14,000 cases were involved. For only three of them (Y_2 broad jump, Y_3 50-yd.dash, and Y_4 softball throw) does the f-value obtained exceed that of 6.66 required for significance at the .01 level of confidence.

When the linear and quadratic regressions were compared, it was found that the coefficients of determination for the quadratic regression shown in Table 23 exceed those for the linear regressions shown in Table 24, by more than one percent.

It is of interest to note the differences between male and female pupils in the degree to which age and physical performance are related. Among the males the indexes of correlation for the quadratic regressions varied from .44 for the shuttle run to .70 for the softball throw. This was shown in Table 5. Among the

Table 27

Values Obtained for Cubic Regression of Each of Five Physical Performances Scores on Height in Inches of 14,486 Female Pupils

Regression Value	Physical Performance (Dependent Variable)				
	Y_1	Y_2	Y_3	Y_4	Y_5
	Shuttle Run	Broad Jump	50-Yd.Dash	Softball Throw	600-Yd. Walk/Run
Regression Coefficient (a)	39.8463	-345.417	42.9806	-798.652	792.740
(b)	-36.9294	323.305	-39.9426	755.342	-573.240
(c)	-5.83998	82.6274	-4.76477	174.423	-272.524
Regression Constant(k)	20.0364	-31.9910	16.6040	-141.459	372.277
Sums of Squares for Regression	1581.76	279.170.0	1281.83	1,400,310.0	393,764.0
Coefficient of Determination	.0341	.1274	.0648	.1919	.0292
Multiple Index of Correlation	.1847	.3569	.2546	.4381	.1709

Table 28

Values Obtained for Quadratic Regression of Each of Five Physical Performances Scores on Height in Inches of 14,486 Female Pupils

	Physical Performance (Dependent Variable)				
Regression Value	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd.Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient (b)	7.41081	-61.0669	7.88519	-133.377	308.903
(c)	-16.1110	171.664	-15.8437	380.288	-476.864
Regression Constant(k)	18.8953	-22.1002	15.3733	-118.590	349.577
Sums of Squares for Regression	1492.73	272,483.0	1178.26	1,364,580.0	358,524.0
Coefficient of Determination	.0322	.1243	.0596	.1870	.0266
Multiple Index of Correlation	.1794	.3526	.2441	.4325	.1631

Table 29

Values Obtained for Linear Regression of Each of Five Physical Performances Scores on Height in Inches of 14,486 Female Pupils

Regression Value	Physical Performance (Dependent Variable)				
	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd.Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk-Run
Regression Coefficient (c)	-7.34136	99.4002	-6.51268	222.455	-111.321
Regression Constant(k)	16.3162	-.847841	12.6291	-72.1727	242.072
Sums of Squares for Regression	1482.59	271,796.0	1166.77	1,361,300.0	340,893.0
Coefficient of Determination	.0320	.1240	.0590	.1866	.0253
Multiple Index of Correlation	.1788	.3522	.2429	.4319	.1591

Table 30

Analyses of Cubic and Quadratic Regression of Physical Performances on Heights of Female Pupils

		Regression Analyses by Dependent Variables								
		Y_1 Shuttle Run			Y_2 Broad Jump			Y_3 50-Yd. Dash		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Cubic Regression	3	1581.76			279,170.0			1281.83		
Quad. Regression	2	1492.73			272,483.0			1178.26		
Difference	1	89.03	89.03	28.81	66,870.0	66,870.0	506.40	103.57	103.57	80.91
Cubic Residual	14,482		3.09			132.05			1.28	
Total	14,485	46,390.2			2,191,500.0			19,771.7		

Table 30 (Continued)

		Y_4 Softball Throw			Y_5 600-Yd. Walk/Run		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Cubic Regression	3	1,400,310.0			393,764.0		
Quad. Regression	2	1,364,580.0			358,524.0		
Difference	1	35,730.0	35,730.0	87.76	35,240.0	35,240.0	39.01
Cubic Residual	14,482		407.12			903.31	
Total	14,485	7,296,290.0			13,475,600.0		

Table 31

Analyses of Quadratic and Linear Regressions of Physical Performances on Heights of Female Pupils

Source of Variation	df	Regression Analyses by Dependent Variables Y_1 Shuttle Run Sum Squ.	Mean Squ.	f	Y_2 Broad Jump Sum Squ.	Mean Squ.	f	Y_3 50-Yd. Dash Sum Squ.	Mean Squ.	f
Quad. Regression	2	1492.73			272,483.0			1178.26		
Linear Regression	1	1482.59			271,796.0			1166.77		
Difference	1	10.14	10.14	3.29	687.0	687.0	5.18	11.49	11.49	8.98
Quad. Residual	14,484		3.10			132.50			1.28	
Total	14,486	46,390.2			2,191,500.0			19,771.7		

Table 31 (Continued)

		Y_4 Softball Throw			Y_5 600-Yd. Walk/Run		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Quad. Regression	2	1,364,580.0			358,524.0		
Linear Regression	1	1,361,300.0			340,893.0		
Difference	1	3,280.0	3,280.0	8.00	17,631.0	17,631.0	19.46
Quad. Residual	14,484		409.56			905.68	
Total	14,486	7,296,290.0			13,475,600.0		

girls the indexes of correlation varied from a low of .21 for the 600-yd. walk/run to a high of .46 for the softball throw. The correlations for the females are considerably lower than those for the males. This shows that physical performances are less predictible from the ages of girls than they are from the ages of boys. It is also of some importance to note that the linear regression was as effective for the boys as was the quadratic from a practical standpoint. However, among the girls, the quadratic regression appeared to show a practical advantage over the linear.

On the basis of the foregoing findings, the null hypotheses, 1) that the cubic regression had no advantage over the quadratic regression of physical performances on age of female pupils could not be rejected, and 2) that the quadratic regression had no advantage over the linear, must be rejected.

2. Height as a Predictor of Physical Performances

The hypotheses concerning the degree and kind of relationship between the height in inches of female pupils and their performance scores on the AAHPER test were evaluated in a manner similar to that described in the preceding analyses. The values for the cubic, quadratic and linear regressions of physical performance scores on pupil height are shown in Tables 27, 28, and 29, respectively.

The analyses of regression are presented in Tables 30 and 31. In Table 30 are shown the comparisons of the cubic with the quadratic regressions of physical performance on height. The comparisons of the quadratic with the linear regression are shown in Table 31. As shown in Table 30, the cubic regressions had

Table 32

Values Obtained for Cubic Regressions of Each of Five Physical Performances on Weight of 14,486 Female Pupils

Regression Value	Physical Performance (Dependent Variables)				
	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd.Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient (a)	-.675462	10.2592	-.674540	17.7420	-2.55594
(b)	4.61669	-64.0764	4.75946	-104.237	67.5320
(c)	-8.02373	109.397	-8.27425	191.437	-135.493
Regression Constant(k)	15.8213	5.35778	12.7296	-40.8753	241,352.0
Sums of Squares for Regression	1023.35	188,609.0	1073.26	1,228,910.0	591,550.0
Coefficient of Determination	.0221	.0861	.0543	.1684	.0439
Multiple Index of Correlation	.1485	.2934	.2330	.4104	.2095

Table 33

Values Obtained for Quadratic Regressions of Each of Five Physical Performances on Weight of 14,486 Female Pupils

Regression Value	Physical Performance (Dependent Variables)				
	Y_1	Y_2	Y_3	Y_4	Y_5
	Shuttle Run	Broad Jump	50-Yd.Dash	Softball Throw	600-Yd. Walk/Run
Regression Coefficient					
(b)	2.13254	-26.3463	2.27870	-38.9867	58.1320
(c)	-5.17195	66.0833	-5.42636	116.531	-124.702
Regression Constant(k)	14.8035	20.8166	11.7132	-14.1413	237.500
Sums of Squares for Regression	1002.28	183,748.0	1052.25	1,214,380.0	591,248.0
Coefficient of Determination	.0216	.0838	.0532	.1664	.0439
Multiple Index of Correlation	.1470	.2896	.2307	.4080	.2094

Table 34

Values Obtained for Linear Regressions of Each of Five Physical Performances on Weight of 14,486 Female Pupils

Regression Value	Physical Performance (Dependent Variables)				
	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd.Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient (c)	-.467562	7.96332	-.399546	30.5265	3.53753
Regression Constant(k)	12.3669	50.9187	9.10964	30.4032	171.081
Sums of Squares for Regression	223.855	64934.7	163.464	954,209.0	12,814.2
Coefficient of Determination	.0048	.0296	.0083	.1308	.0010
Multiple Index of Correlation	-.0695	.1721	-.0909	.3616	.0308

Table 35

Analyses of Cubic and Quadratic Regressions of Physical Performances on Weights of Female Pupils

		Regression Analyses by Dependent Variables								
		Y_1 Shuttle Run			Y_2 Broad Jump			Y_3 50-Yd. Dash		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Cubic Regression	3	1023.35			188,609.0			1073.26		
Quad. Regression	2	1002.28			183,748.0			1052.25		
Difference	1	21.07	21.07	6.73	4,861.0	4,861.0	35.15	21.01	21.01	16.28
Cubic Residual	14,483		3.13			138.302			1.29	
Total	14,486	46,390.2			2,191,500.0			197,717.0		

Table 35 (Continued)

		Y_4 Softball Throw		f	Y_5 600-Yd. Walk/Run		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Cubic Regression	3	1,228,910.0			591,550.0		
Quad. Regression	2	1,214,380.0			591,248.0		
Difference	1	15,530.0	15,530.0		302.0	302.0	
Cubic Residual	14,483		418.96	37.07		889.65	<1
Total	14,486		7,296,290.0			13,475,600.0	

Table 36

Analyses of Quadratic and Linear Regressions of Physical Performances on Weights of Female Pupils

		Regression Analyses by Dependent Variables								
		Y_1			Y_2			Y_3		
		Shuttle Run			Broad Jump			50-Yd. Dash		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
Quad. Regression	2	1002.28			183,748.0			1052.25		
Linear Regression	1	223.86			64,934.0			163.46		
Difference	1	778.42	778.42	>260	118,814.0	118,814.0	>800	888.79	888.79	>600
Quad. Residual	14,484		3.13			138.63			1.29	
Total	14,486	46,390.2			2,191,500.0			197,717.0		

Table 36 (Continued)

Source of Variation	df	Y_4 Softball Throw Sum Squ.	Mean Squ.	f	Y_5 600-Yd. Walk/Run Sum Squ.	Mean Squ.	f
Quad. Regression	2	1,214,380.0			591,248.0		
Linear Regression	1	954,209.0			12,814.0		
Difference	1	260,171.0	260,171.0	>600	478,434.0	478,434.0	>500
Quad. Residual	14,484		419.93			889.62	
Total	14,486	7,296,290.0			13,475,600.0		

significant advantages over the quadratic. With the exception of the regression of the shuttle run performance (Y_1) the quadratic regression was significantly superior to the linear regressions of physical performances on the height of female pupils. A reference to the coefficients of determination shown in Tables 27, 28, and 29 will reveal that the linear regression accounted for only a fraction of one percent less of the total sums of squares of variation in the dependent variates than did the cubic regressions. For all practical purposes the linear regressions were as good as the cubic and the quadratic.

3. Weight as a Predictor of Physical Performances

The analyses of the regressions of physical performances on the weights of female pupils are shown in Tables 32 through 36.

Reference to Tables 32 through 34 will reveal, that with the exception of the softball throw, weight is not closely related to the physical performances. The cubic relationship was shown in Table 35 to have a significant advantage over the quadratic for all performances except the 600-yd. walk/run. But the differences, although significant, were inconsequential as shown by comparing the coefficients of determination in Table 32 with those in Table 33. From these comparisons it can be seen that the cubic regressions could account for less than one-half of one percent more of the variability of the dependent variables than did the corresponding quadratic regressions.

The interesting differences which appeared in these analyses were those between the linear and the quadratic regressions. The f-values shown in Table 36 for these differences are all extremely

Table 37

Values Obtained for Five Variable Multiple Regressions of Five Physical Performance Scores for 14,486 Female Pupils

	Physical Performance (Dependent Variables)				
Regression Value	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd.Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient (a)	1.83559	-11.7824	1.16290	-26.5778	32.6148
(b)	-7.36889	52.2816	-4.73456	106.112	-129.420
(c)	-5.63499	84.1930	-5.58068	75.6266	-175.458
(d)	.106691	-4.46231	.712641	-10.7347	14.0456
(e)	1.13753	-3.15734	-.509502	28.6739	13.9133
Regression Constant(k)	20.8667	-35.1347	16.2399	-99.8231	370.141
Sums of Squares for Regression	3193.99	431,374.0	2294.35	1,643,230.0	1,541,100.0
Coefficient of Determination	.0700	.1968	.1160	.2252	.1143
Multiple Index of Correlation	.2624	.4436	.3407	.4746	.3382
Standard Error of Estimate	1.73	11.03	1.10	19.76	28.71

Table 38

Value Obtained for Prediction of Physical Performances of Female Pupils on their Heights and Weights

Regression Value	Physical Performance (Dependent Variables) Y_1 Shuttle Run	 Y_2 Broad Jump	 Y_3 50-Yd.Dash	 Y_4 Softball Throw	 Y_5 600-Yd. Walk/Run
Regression Coefficient					
(c)	-11.4695	136.341	-9.47215	158.384	-274.669
(d)	-756,713.0	-9.99143	1.14246	-19.9876	25.1839
(e)	-.678082	12.6633	-1.71507	54.4745	-17.0833
Regression Constant(k)	18.6405	-24.7950	14.8820	-67.1271	329.388
Sums of Squares for Regression	2117.91	341,395.0	1813.15	1,427,120.0	123,106.0
Coefficient of Determination	.0457	.1558	.0917	.1956	.0914
Multiple Index of Correlation	.2137	.3947	.3028	.4423	.3023

Table 39

Value Obtained for Prediction of Physical Performances of Female Pupils on their Ages and Weights

Regression Value	Physical Performance (Dependent Variables)				
	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd.Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient					
(a)	2.27691	-18.3763	1.59997	-32.5008	46.3565
(b)	-9.07159	77.7218	-6.42085	138.964	-182.438
(d)	.501288	-10.3580	1.10343	-16.0306	26.3323
(e)	-.221621	17.1498	1.85555	46.9149	-28.4068
Regression Constant(k)	19.9727	-21.7775	15.3545	-87.8251	342.304
Sums of Squares for Regression	2982.80	384,054.0	2086.44	1,605,060.0	1,335,590.0
Coefficient of Determination	.0643	.1752	.1055	.2200	.0991
Multiple Index of Correlation	.2535	.4186	.3248	.4690	.3148

Table 40

Values Obtained for Prediction of Physical Performances of Female Pupils on their Ages and Heights

Regression Value	Physical Performance (Dependent Variables) Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd.Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient					
(a)	2.03578	-14.6731	1.49936	-29.0526	42,2047
(b)	-7.76885	59.3975	-5.65161	115.382	-152.679
(c)	-5.28808	32.3346	-1.44349	99.1631	4.02531
Regression Constant(k)	18.9318	-16.1832	14.6276	-104.834	304.943
Sums of Squares for Regression	2420.55	350,360.0	1624.43	1,626,720.0	593,005.0
Coefficient of Determination	.0522	.1599	.0822	.2230	.0440
Multiple Index of Correlation	.2284	.3998	.2866	.4722	.2098

Table 41

Regression Analyses to Evaluate Contributions of Ages, Heights, and Weights to the Complex Multiple Regression of Physical Performances

		Y_1 Shuttle Run			Y_2 Broad Jump			Y_3 50-Yd. Dash		
Source of Variation	df	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f	Sum Squ.	Mean Squ.	f
1) Complex Multiple Regression	5	3193.99			431,374.0			2294.35		
2) Regression without Age	3	2117.91			341,395.0			1813.15		
3) Regression without Height	4	2982.80			384,054.0			2086.44		
4) Regression without Weight	3	2420.55			350,360.0			1624.43		
Differences										
5) 1 - 2	2	1076.28	538.14	180.6	89.979.0	44,989.5	368.9	481.20	240.6	198.8
6) 1 - 3	1	211.90	211.90	71.1	47,320.0	47,320.0	388.8	207.91	207.9	171.8
7) 1 - 4	2	773.44	386.72	129.7	81,014.0	40,507.0	332.2	669.92	334.96	276.8
8) Complex Mult. Residuals	14,480	43,196.2	2.98		1,760,126.0	121.56		17,477.35	1.21	
9) Total	14,485	46,390.2			2,191,500.0			19,771.7		
Partial Corr.										
10) $R_{Y_p X_1^2 \cdot X_2 X_3^2}$		.1558	-		.2427	-		.1634	-	
11) $R_{Y_p X_2 \cdot X_1^2 X_3^2}$		.0699	-		.1615	-		.1081	-	
12) $R_{Y_p X_3^2 \cdot X_1^2 X_2}$		.1326	-		.2097	-		.1921	-	

Table 41 (Continued)

Source of Variation	df	Y_4 Softball Throw Sum Squ.	Mean Squ.	f	Y_5 600-Yd. Walk/Run Sum Squ.	Mean Squ.	f
1) Complex Multiple Regression	5	1,643,230.0			1,541,100.0		
2) Regression without Age	3	1,427,120.0			1,231,060.0		
3) Regression without Height	4	1,605,060.0			1,335,590.0		
4) Regression without Weight	3	1,626,720.0			593,005.0		
Differences							
5) 1 - 2	2	216,110.0	108,055.0	276.79	310,040.0	155,020.0	187.6
6) 1 - 3	1	38,170.0	38,170.0	97.77	205,110.0	205,110.0	248.2
7) 1 - 4	2	16,510.0	8,255.0	21.14	948,095.0	474,047.5	573.6
8) Complex Mult. Residuals	14,480	5,653,060.0	390.40		11,934,500.0	824.20	
9) Total	14,485	7,296,290.0			13,475,600.0		
Partial Corr.							
10) $R_{Y_p X_1^2 \cdot X_2 X_3^2}$		.1918	-		.1590	-	
11) $R_{Y_p X_2 \cdot X_1^2 X_3^2}$		.0816	-		.1296	-	
12) $R_{Y_p X_3^2 \cdot X_1^2 X_2}$		.0538	-		.2711	-	

large. Thus, the advantages of the quadratic regression over the linear were substantial. In fact, the linear regression of the shuttle run scores on pupil weight could account for only .48 of a percent of the sum of squared deviations in the shuttle run. The linear regressions could account for only about 3 percent of the sums of squares of the broad jump and 13 percent of the sums of squares of the softball throw and less than 1 percent of the sums of squares of the other three dependent variables. It must be concluded, therefore, that the physical performances of female pupils, as revealed by their scores on the five AAHPER items included in this study, are not linear functions of pupil weights, but are quadratic functions of pupil weights.

E. Testing Multiple Variable Hypotheses Among Female Pupils

The findings of the immediately preceding analyses were that the physical performances of female pupils could be most satisfactorily predicted by a quadratic function of age, by a linear function of height and by a quadratic function of weight. The most effective of all regressions would be the composite of all of these. Such a composite regression equation would have the form:

$$\sum_{1-N} Y_p = a\sum_{1-N} (x/100)^2 + b\sum_{1-N} (x_1/100) + c\sum_{1-N} (x_2/100)$$

$$+ d\sum_{1-N} (x_3/100)^2 + \Sigma e_{1-N} (x_3/100 + Nk$$

Where:

x_1 = Pupil in months
x_2 = Pupil height in inches
x_3 = Pupil weight in pounds
Y_p = Item score on AAPHER test (p = 1 --- 5)
N = 14,486

Values were obtained for the foregoing regression equation. They are shown in Table 37. It can be seen from the coefficients of determination, shown in Table 37, that the regressions accounted for 7 percent of the sums of squares for the shuttle run, for about 11 1/2 percent for each of the 50-yd. dash, and 600-yd. walk/run. The greatest portions of the sums of squares were accounted for by the regression of the broad jump scores, just under 20 percent and of the softball throw, 22 1/2 percent.

In view of the large numbers of cases involved, f-tests of the significance of these regressions would produce f-values far in excess of those required for significance at the .01 level. It only remained necessary to test the significance of the individual contribution of each independent variable to the regression system. This was done in the manner previously used with the male pupils. Each of the variables age, height and weight were disregarded in turn and the regression equation was calculated for the other two. The sums of squares for the smaller regression equations were compared with those of the larger equations and the differences were tested for significance.

When age was eliminated from the regression system, an equation of the form:

$$Y_p\Sigma = c\Sigma(x_2/100) + d\Sigma(x_3/100)^2 + e\Sigma(x_3/100) + Nk$$

was obtained. The values obtained for these equations are shown in Table 38 for the regression from which age was eliminated, in Table 39 for the regression from which height was eliminated and Table 40 for the regression from which weight was eliminated. The regression analyses which were used to evaluate the contribution of each of the pupil characteristics of age, height, and weight to the multiple nonlinear regression are summarized in Table 41. The f-values obtained for the differences in regression sums of squares between the most complex equations and the less complex equations were all many times greater than that required for significance at the .01 level of confidence. Thus, it appeared that each of the three variables through its particular function contributed a significant amount to the sums of squared variations of the dependent variate which could be accounted for by regression on the independent variates.

However, the importance of the contribution of each of the three independent variables can be best indicated by its partial correlation with the dependent variables when each of the other independent variables are held constant. For this purpose the complex partial correlations shown at the bottom of Table 41 were calculated by use of the following formula:

$$R_{Y_p X_1^2 \cdot X_2 X^2} = \sqrt{\frac{\text{loss in sums of squares due to elimination of } X_1 \text{ from regression}}{\text{loss in sums of squares due to elimination of } X \text{ from regression + residual sums of squares for complex nonlinear regression}}}$$

The first row of correlation values in Table 41 represent the relationships between pupil age in months, and each of the five physical performance scores when height and weight are held constant. It can be seen that age is the variable which makes the largest contribution to the regression of the shuttle run, broad jump and softball throw scores. Weight is the variable which makes the largest unique contribution to the regression of the 50-yd. dash and the 600-yd. walk/run scores. Body weight contributed nearly as much as age to the regression of the shuttle run and the broad jump scores. Body weight was least important in the regression of the softball throw scores.

It is of interest to note the variables which were most important in the regression of each of the physical performance scores. Age and weight were almost equally important in the regression of the shuttle run scores. Pupil height was relatively unimportant in this regression. In the regression of broad jump scores, age, and weight were most important. But height made a substantial contribution to the regression. In the regression of the 50-yd. dash performance of female pupils, weight was the largest unique contributor closely followed by age. In this regression, height made a lesser contribution than did the other two characteristics. In the regression of softball throwing distances, age of pupils made the greatest unique contribution. Height and weight made very small unique contributions to the regression of softball throwing distances. Weight made a very heavy contribution to the regression of the 600-yd. walk/run performance scores. Age and height made substantial, but much smaller contributions.

IV Conclusions and Implications

A. General Conclusions

There are a number of conclusions which may be drawn from the findings which were presented in the foregoing sections of this report. It was found that the pupil characteristics of age, height, and weight were each substantially related to the five physical performance scores achieved by male pupils on the AAHPER Youth Fitness Test. It was found that of the three pupil characteristics, weight was the only one for which its relationships with the five performance scores were more effectively expressed by quadratic functions than by linear functions. Furthermore, it was found that each of the pupil characteristics made a significant and substantial contribution to the multiple variable prediction of each of the performance scores, with the exception of the contribution of weight to the prediction of softball throwing performance scores. From these findings it must be concluded that the physical performance scores obtained by male pupils on the AAHPER Youth Fitness Test cannot be adequately interpreted unless their ages in months, heights in inches, and weights in pounds are taken into account.

With the female pupils it was found that the pupil characteristics of age, height, and weight were much less strongly related to the five physical performances, as revealed by scores made on the AAHPER Youth Fitness Test, than they were with the male pupils. However, it was found that among the female pupils the relationships between age, and the physical performance scores, and between weight and the physical performance scores could be more effectively expressed as quadratic functions. Furthermore, it was also found that with two exceptions the three-pupil characteristics made unique and substantial contributions to the prediction of the physical performance scores. The two exceptions were (1) pupil height as a predictor of the shuttle run performance scores and (2) pupil weight as a predictor of the softball throwing scores. It must be concluded, therefore, that the scores made by female pupils on the standing broad jump, the 50-yd. dash, and the 600-yd. walk/run items of the AAHPER Youth Fitness Test cannot be adequately interpreted unless their ages in months, heights in inches, and weights in pounds are taken into account. The scores made on the shuttle run by females cannot be adequately interpreted unless age and weight are taken into account, and the scores made by females on the softball throw item cannot be adequately interpreted unless pupil ages and weights are taken into account.

Among both the males and females it was noted that the three-pupil characteristics in combination were not closely related to the performances which did not require running. In other words, the broad jump scores and softball throwing scores of both boys and girls are more predictible than are the shuttle run, 50-yd. dash and the 600-yd. walk/run scores. It is reasonable to suppose that this would hold true for any other non-running items which might be added to the AAHPER Test.

There are two major implications arising from this study. The first and most important is that the necessity for taking a pupil's age, height, and weight into account in the interpretation of his performances on the AAHPER Test (or any other physical performance test for that matter) requires that a whole new set of norms for performance be developed. Such a set of norms has been developed on Minnesota children. They will be described later in this report.

The second major implication of the findings of this study is that a score for each of the five performances can be devised which may be combined into a composite score.

B. Norms for the Performances of Minnesota Children on the Five Items of the AAHPER Test

The purposes of the "norms" here presented are to (1) provide a reasonable, "normal" expectation for the performance on the five items of the AAHPER Test of children of various ages, heights, and weights, and (2) to provide a basis for judging the quality of performance in terms of the degree to which they exceed or are exceeded by the "normally" expected performance level. These purposes may be attained through the use of the regression equations which were developed in this study.

The findings of this research project were that the best prediction of the performance of male pupils on the five AAHPER Test items could be obtained from equations of the form:

$$Y_p = ax_1 + bx_2 + cx_3^2 + dx_3 + k$$

Where:

Y_p = One of the AAHPER Performance score expectations

x_1 = Age in months

x_2 = Height in inches

x_3 = Weight in pounds

a, b, c, d, and k, are appropriate coefficients and constants shown in Table 42. The values in Table 42 were derived

Table 42

Multiple Nonlinear Regression Coefficients for Predicting Male Pupil Performances Scores on AAHPER Test Adjusted for the Scaling of Variables

Regression Value	Physical Performance (Dependent Variables) Y_1 Shuttle Run	 Y_2 Broad Jump	 Y_3 50-Yd.Dash	 Y_4 Softball Throw	 Y_5 600-Yd. Walk/Run
Regression Coefficient					
(a)	-.02448	.2446	-.019216	.57788	-.668677
(b)	-.04796	.9515	-.064489	2.05824	-2.25012
(c)	.000013	.00009	.000023	-.0011611	-.000327
(d)	.00588	-.1185	.002031	.399821	.48298
Regression Constant(k)	17.0062	-19.1151	14.4222	-119.286	336.005
Standard Error of Estimate	1.296	8.651	.9238	26.1382	22.7812

Table 43

Multiple Nonlinear Regression Coefficients for Predicting Female Pupil Performances Scores on AAHPER Test Adjusted for the Scaling of Variables

Regression Value	Physical Performance (Dependent Variables)				
	Y_1 Shuttle Run	Y_2 Broad Jump	Y_3 50-Yd.Dash	Y_4 Softball Throw	Y_5 600-Yd. Walk/Run
Regression Coefficient					
(a)	.000184	-001178	.000116	-.002658	.003261
(b)	-.073689	.522816	-.047345	1.061120	-1.29420
(c)	-.056350	.841930	-.055807	.756266	-1.75458
(d)	.000011	-.000446	.000071	-.001073	.001405
(e)	.011375	-.031573	-.005095	.286739	.139133
Regression Constant(k)	20.8667	-35.1347	16.2399	-99.8231	370.141
Standard Error of Estimate	1.73	11.03	1.10	19.76	28.71

from those shown in Table 16, by adjusting them to compensate for the scaling which was done to facilitate the computer processing.

The best expectation for the performances of female pupils could be obtained from an equation of the form:

$$Y_p = ax_1^2 + bx_1 + cx_2 + dx_3^2 + ex_3 + k$$

Where:

Y_p = One of the AAHPER performance score expectations

x_1 = Age in months

x_2 = Height in inches

x_3 = Weight in pounds

and a, b, c, d, e, and k, are the appropriate regression coefficients and constants shown in Table 43. These values were derived from Table 37.

The most direct means of obtaining a level of expectation for the performance of a pupil would be to insert into one of the foregoing equations the values of the pupil's age, height, and weight and solve for Y_p.

For example, to determine the expected broad jump performance of a boy who is 12 years and 3 months of age, 62 inches tall and weighs 115 pounds, the equation would be as follows:

$$\text{Broad jump distance in inches} = .2447(1477 \text{ mo.}) + .9515(62 \text{ in.}) + .00009(115 \text{ lb.}^2) - .1185(115 \text{ lb.}) - 19.1151 = 63.41 \text{ inches}$$

The 63.41 inches obtained from the solution of the foregoing equation represents the average performance of all boys who are of the same age, height, and weight. Thus, it can be assumed that the broad jump performance of boys 147 months of age, 62 inches tall, and 115 pounds in weight would be normally distributed with a mean value of 63.41 inches. The best estimate of the standard deviation of this distribution is the standard error of estimate which can be obtained from the regression equation. The actual performance of pupils may be evaluated in terms of their standard scores. Suppose that the pupil in question had jumped a distance of 72 3/4 inches. A standard score could be calculated using the following equation:

$$\text{standard score} = \frac{\overset{Y}{\text{actual}} - \overset{Y}{\text{expected}}}{\sigma\text{SE of estimate}}$$

Substituting into the foregoing equation, the values for the student in question and solving the following is obtained:

$$\frac{72.75 - 63.41}{8.637} = 1.08$$

It is suggested that standard scores might be interpreted as is indicated in Table 44.

Table 44

Suggested Letter-grade Equivalents for Standard Scores for Performances on Items of the AAHPER Youth Fitness Test

Standard Score Range	Letter-Grade
+3 and over	A
+1 to +2	B
-1 to +1	C
-2 to -1	D
less than -2	F

It would be a tedious and time consuming task to apply the regression equation values to the individual ages, heights, and weights for each pupil in a grade in a school. Therefore, norm tables have been prepared using the regression equation. These tables are shown in Appendix A for boys, and Appendix B for girls. Expected performances for pupils of various ages, heights, and weights may be obtained from the tables.

C. Development of a Composite Score for the Five Items of the AAHPER Test

It was one of the objectives of this study to determine the possibility of developing a composite score for the items of the AAHPER which were the concern of this research project. An essential condition which must be met before the combination of item scores is possible, is that each of the item scores be expressed in the same units. The raw score of the items are expressed as time required to travel given distances, or as the length of a jump, or softball throw. It is impossible to make any meaningful combination of these units.

However, the standard scores, whose derivation is described in the preceding section meet the condition of equality of units. Thus, they are additive and may be averaged in the usual manner. The average standard score may be interpreted in the same manner as an individual performance score using the evaluations suggested in Table 44. To obtain an overall performance score for an individual pupil, the following steps should be followed:

1. Obtain the five-item raw scores for the pupil together with his age in months, height in inches and weight in pounds.

2. Use norm tables to obtain expected performance scores for each of the five performances.
3. Calculate five standard scores using the formula:

$$\text{Standard Performance Score} = \frac{Y_{\text{actual}} - Y_{\text{expected}}}{\sigma SE}$$

Where SE is the standard error of estimate shown in Table 42 for boys and Table 43 for girls.

4. Add the five standard scores together.
5. Divide the sum by 5 (the number of items).

The foregoing procedure is based on the assumption that all of the items are of equal value in determining the overall performance of pupils. If it is assumed that the items are not equally important, it might be necessary to weight one or more of the items standard scores so that it would have a proportionally greater influence on the composite score. For example, if stamina as revealed by the scores on the 600-yd. walk/run is twice as important as are speed, agility and power as revealed by the other four items, a composite score could be obtained by following the first three steps as previously suggested. The fourth step would be to double the 600-yd. walk/run standard score. The fifth step would then be to sum the resulting standard scores, and the sixth would be to divide the resulting sum by six (the number of items making up the sum was four individual items and one doubled item). A wide variety of combinations by which a composite score for this test may be obtained may be developed depending on the philosophy of physical education which has been adopted in a particular school. A composite score may be derived for any particular relative weighting of the items.

Various other procedures for weighting the item scores before combining them into a composite score might be suggested. For example, factor loadings from a factor analysis might be used. This would only be feasible if some general factor could be identified which could be termed the "general fitness factor". The procedure proposed here has the advantages of simplicity and flexibility which will allow it to be effective for any degree of emphasis that might be placed upon physical education programs.